A COMPARISON OF TWO TARGET COVERAGE MODELS

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THESIS

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ABSTRACT

This thesis examines several models for the computation of target coverage when multiple rounds are fired at a target. Fractional kill of a fragment sensitive target by a fragmenting projectile as a function of the number of rounds fired is compared for two models. The first is a standard salvo-fire model in which N rounds are fired at the same aim point. In the second model, single shot kill probability is computed for a fragment sensitive target and then fractional kill from the firing of N rounds is computed according to the assumption that the effects of each round are independent. The need for sophisticated target coverage models (such as salvo-fire models) is demonstrated by the results of computations performed in this study.

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TABLE OF SYMBOLS AND ABBREVIATIONS

A list of symbols used in the text and computer programs is given below.

ENGLISH SYMBOLS

Text Symbol	Definition	Computer Name
a	lethal radius of projectile	A
a_x	lethal radius in range	AX
a_y	lethal radius in deflection	AY
B	ballistic error	
$\underline{b}(x,y;\bar{x},\bar{y})$	probability density function of ballistic error	
D	damage measure	
d	deflection	
$\underline{d}(p,q;x,y)$	damage function	
$\bar{F}_N$	average fraction of target killed with salvo of N rounds using dependent model	F(N) AFTK
$\bar{F}^*_N$	average fraction of target killed with salvo of N rounds using independent model	TERMIN(N) AFTK (INDEP)
L	target location error	
$\underline{l}(U,V;u,v)$	probability density function of target location error	
N	number of projectiles	N NRDS
O	intentional offset	
(p,q)	location of target element	
PE_r	probable error in range	

Text Symbol	Definition	Computer Name
PE_d	probable error in deflection	
PK_N	cumulative kill probability with salvo of N rounds using dependent model	PKILL(N)
PK_N^*	cumulative kill probability with salvo of N rounds using independent model	PINDEP(N) PKILL(INDEP)
P_{k/x_a}	probability of killing target located at $x=0$ with one round given aim point is x_a	
$P_{k/\overline{x},\overline{y}}$	probability of killing target with one round given aim point is $\overline{x},\overline{y}$	
R, r	range	
(u,v)	postulated location of target reference point	
(U,V)	actual location of target reference point used by fire direction center	BX,BY
W	target density or weighting measure	
$\underline{w}(p,q;u,v)$	target density or area weighting function	
(x,y)	point of projectile impact	
$(\overline{x},\overline{y})$	aim point for 2D model	
x_a	aim point for 1D model	
x_b	distance from point of impact to aim point	
x_{b_i}	distance ith round impacts from aim point	

GREEK SYMBOLS

Text Symbol	Definition	Computer Name
σ_a	target location error standard deviation	SIGA
σ_{a_x}	target location error standard deviation in range	SIGAX

Text Symbol	Definition	Computer Name
σ_{a_y}	target location error standard deviation in deflection	SIGAY
σ_b	ballistic error standard deviation	SIGD
σ_{b_x}	ballistic error standard deviation in range	SIGDX
σ_{b_y}	ballistic error standard deviation in deflection	SIGDY
σ_t	target density standard deviation	SIGT
σ_{t_x}	target density standard deviation in range	SIGTX
σ_{t_y}	target density standard deviation in deflection	SIGTY
μ_a	mean aim point for 1D model	AMU
μ_x	mean target location error in range	BX
μ_y	mean target location error in deflection	BY

I. INTRODUCTION

A. TARGET COVERAGE MODELS

Since their development over 20 years ago, target coverage models have been used to provide insight into the effectiveness of artillery weapons systems and problems of weapons system design and associated force structure analysis. More recent work by C. H. Hess [10] has been directed toward providing a model adaptable to operational use by combat commanders. These models are used to calculate the fractional kill of a fragment sensitive target by a fragmenting projectile as a function of the number of rounds fired.

In this thesis a standard salvo-fire model in which N rounds are fired at the same aim point was compared to a model which assumes that the effects of each of the N rounds fired are independent. In the latter model, single shot kill probability is computed for a fragment sensitive target and then fractional kill from the firing of N rounds is computed according to the independence assumption.

Because of the great simplification in expression for the computation of cumulative target effects, it has been assumed in some target coverage studies that the effects of multiple rounds from the same weapon fired at a single target were independent. For example, this was done in the recent Marine Amphibious Force Fire Support Study (U) [12, 13]. More realistic and (unfortunately) complex models of such a tactical

situation are available. In light of increased costs in both computational time and analysis effort, it is of interest to examine whether such sophistications are justified. Hence, this thesis compared these modeling alternatives.

B. PURPOSE

The purpose of this thesis was to compare in detail a model which used the independence of effects of rounds assumption with a standard salvo-fire model.

C. SALVO MODELS

In a salvo-fire model it is assumed that (1) the aim point is constant for all N rounds and (2) the N rounds are fired more or less simultaneously [11]. From this salvo model, one computes the expected fractional kill by N rounds all having the same lethal area and all aimed at the same point relative to the target center [1].

The above model describes numerous tactical situations among which are (1) one artillery tube sequentially fires N identical rounds at the same aim point and (2) N artillery tubes fire identical rounds simultaneously at the same aim point from the same location. Elsewhere in this thesis there is a partial analysis of the vast spectrum of artillery operations. The salvo-fire model specifically applies (without any modification) to the case when N rounds are sequentially fired at the same aim point without changes in this aim point due to updated intelligence about the target during the firing sequence. This is called unadjusted fire and according to

FM 6-40 [4]:

> "The greatest demoralizing effect on the enemy can be achieved by delivering a maximum number of rounds . . . in the shortest possible time and without adjustment."

II. THE GENERAL TARGET COVERAGE MODEL

A. ANALYSIS OF THE ARTILLERY SYSTEM

The forward observer (FO) who maintains communication with the fire direction center (FDC) is normally located between the firing battery and the enemy target, and attempts to move about the battlefield in such a manner as to achieve a commanding field of view while maintaining concealment. He is responsible for target acquisition which includes detection (the determination of the existence or presence of a target), identification (the determination of the nature, composition and size of the target, and location (the determination of the three dimensional coordinates of the target), of ground targets for the purpose of effective employment of supporting weapons [2].

The FO transmits this information to the FDC which consists of gunnery, intelligence, and communication elements. The FDC is the element of the artillery headquarters through which the commander exercises fire direction and control. The FDC translates the information received from the FO into the appropriate fire commands and transmits the commands to the batteries [3]. The gun crews then set the proper elevation and azimuth readings on the guns and engage the target as directed.

An error free execution of this process would result in positive destruction of the target. It is the introduction

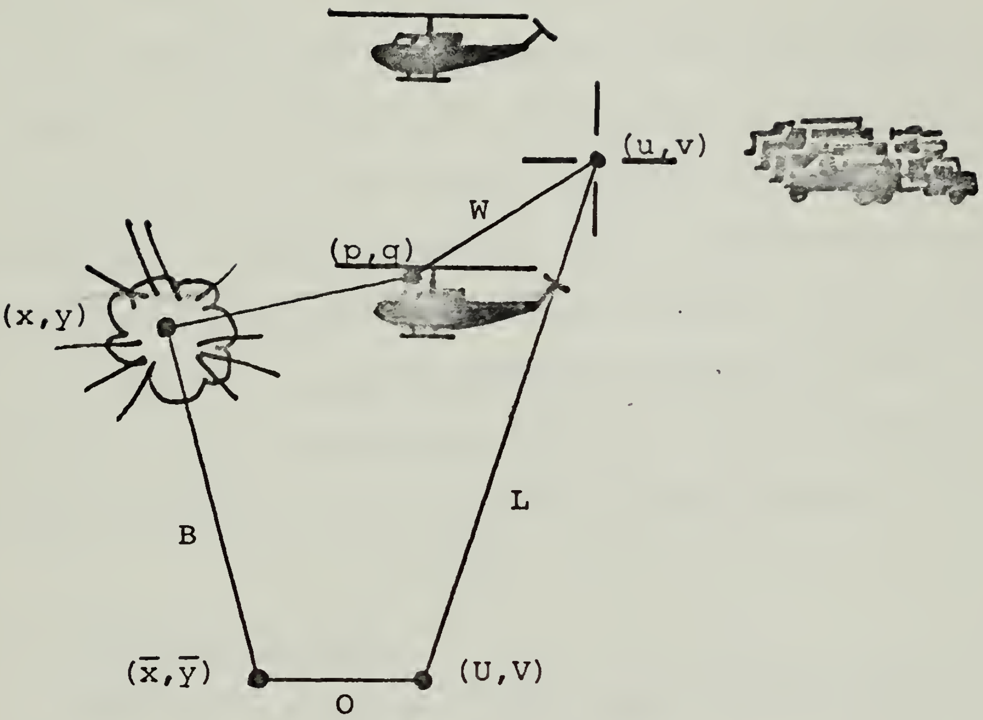
of errors that creates the target coverage problem (see Figure 1). The FO makes errors in locating and reporting the target. The FDC makes errors in translating the location of the target into gun settings. The gun crews make errors in placing the settings on the guns and finally nature creates errors in the trajectory of the projectile due to such variabilities as tube wear, temperature, humidity, and wind variation. The general target coverage problem is to determine expected damage to the target from knowledge about these errors (their distributions) and from knowledge of intentional offsets, lethality and target density functions.

B. DELIVERY ERRORS

The system delivery errors present in the general target coverage model are errors inherent to the system and are composed of (1) the target location error which may alternatively be thought of as an aiming error, and (2) the ballistic error. Target location (aim) errors in range and deflection are associated with the entire delivery system while ballistic errors are associated with individual weapons.

1. Target Location Errors

Field artillery cannon targets are located by an artillery forward observer who identifies the target and reports its location to the Fire Direction Center. These targets are imprecisely located due to errors in target acquisition and possible movement by the target in the time interval between acquisition and attack. The target's reported position (U,V) which is the aim point for the artillery tube if there is no



Symbol	Definition	Distribution
L	target location error	$\underline{l}(U,V;u,v)$
O	intentional offset	deterministic
B	ballistic error	$\underline{b}(x,y;\bar{x},\bar{y})$
D	damage measure	$\underline{d}(p,q;x,y)$
W	target density or weighting measure	$\underline{w}(p,q;u,v)$

$$\overline{F}_n = \int\int\int\int\int\int\int\int \underline{l}(U,V;u,v)\,\underline{b}(x,y;\bar{x},\bar{y})\,\underline{d}(p,q;x,y)\,\underline{w}(p,q;u,v)\,dp\,dq\,dU\,dV\,d\bar{x}\,d\bar{y}\,dx\,dy$$

Figure 1. General Target Coverage Model.

intentional offset is distributed with respect to the true target centroid (u,v) according to some probability density function, $\underline{l}(U,V;u,v)$. The usual assumption is that $\underline{l}(U,V;u,v)$ has the form of a noncorrelated bivariate normal distribution. If there is no mean target location error, then L is centered on the true target location and its distribution is symmetric. USACDCEC Experiment 31.1 [16] has shown that the mean target location errors are nonzero, the range error being significantly greater than the deflection error. Thus, the more realistic assumption is that L is distributed as a bivariate normal with $\sigma_{a_x} > \sigma_{a_y}$ and a nonzero mean.

2. Ballistic Errors

SWEM [14] considers three types of ballistic errors; normal, uniform, and stick which is a combination of a uniform and a normal distribution. The impact of rounds at (x,y) is distributed according to some probability density function $\underline{b}(x,y;\overline{x},\overline{y})$. For artillery coverage problems, the common assumption is that B has a noncorrelated bivariate normal distribution since, by the Central Limit Theorem, the sum of a number of independent well-behaved random variables can be expected to approach normality.

C. TARGET DENSITY FUNCTIONS

Hess [10] defines a target as a collection of elements (considered either as points or area increments) which are located in an area. Each target element (p,q) is independently and identically distributed at the target location according to

a target density function $\underline{w}(p,q;u,v)$ which has properties of a probability density function. For a continuously distributed target such as an airfield runway, the elements would be treated as area increments and the target density would be uniform. A uniform distribution might also be appropriate for ammunition storage bunkers dispersed over an area, but in this case the target elements would be points.

The target density function does double duty because it can also be thought of as an area weighting function. If the target is an infantry unit deployed over an area, that subarea occupied by the unit leader should be weighted more heavily than areas of equal size occupied by non-leaders. This distribution of weight over the target area would result in a peaked, non-uniform distribution. The most common form of W has been the uniform distribution in some specified square, rectangular, circular or elliptical area.

D. DAMAGE (LETHALITY) FUNCTIONS

Field artillery cannons firing fragmenting projectiles kill fragment.sensitive targets by exploding and throwing off schrapnel. Thus, it is not necessary for a direct hit to occur in order for the round to be effective. The damage function resulting from the exploding rounds depends on both the target element location (p,q) and the impact point (x,y) and is denoted by $\underline{d}(p,q;x,y)$.

The simplest and most common form of the damage function is a cookie cutter (see Figure 2(a)). This form specifies a constant amount of damage out to some range R from point of

impact, beyond which there is zero damage. Other more accurate but more complicated damage functions are available which give a more realistic estimate of true projectile lethality (see (b) through (f) in Fig. 2). Figure 3 from BRL report 1544 [1] compares a poor damage function (the cookie cutter), a good damage function (the exponential), and the true function.

E. BIAS

Bias is the sum of the mean target location error and any intentional offset from the actual target centroid and determines the location of aim point $(\overline{x},\overline{y})$ with respect to the target centroid. When there is no intentional offset, $(U,V)=(\overline{x},\overline{y})$.

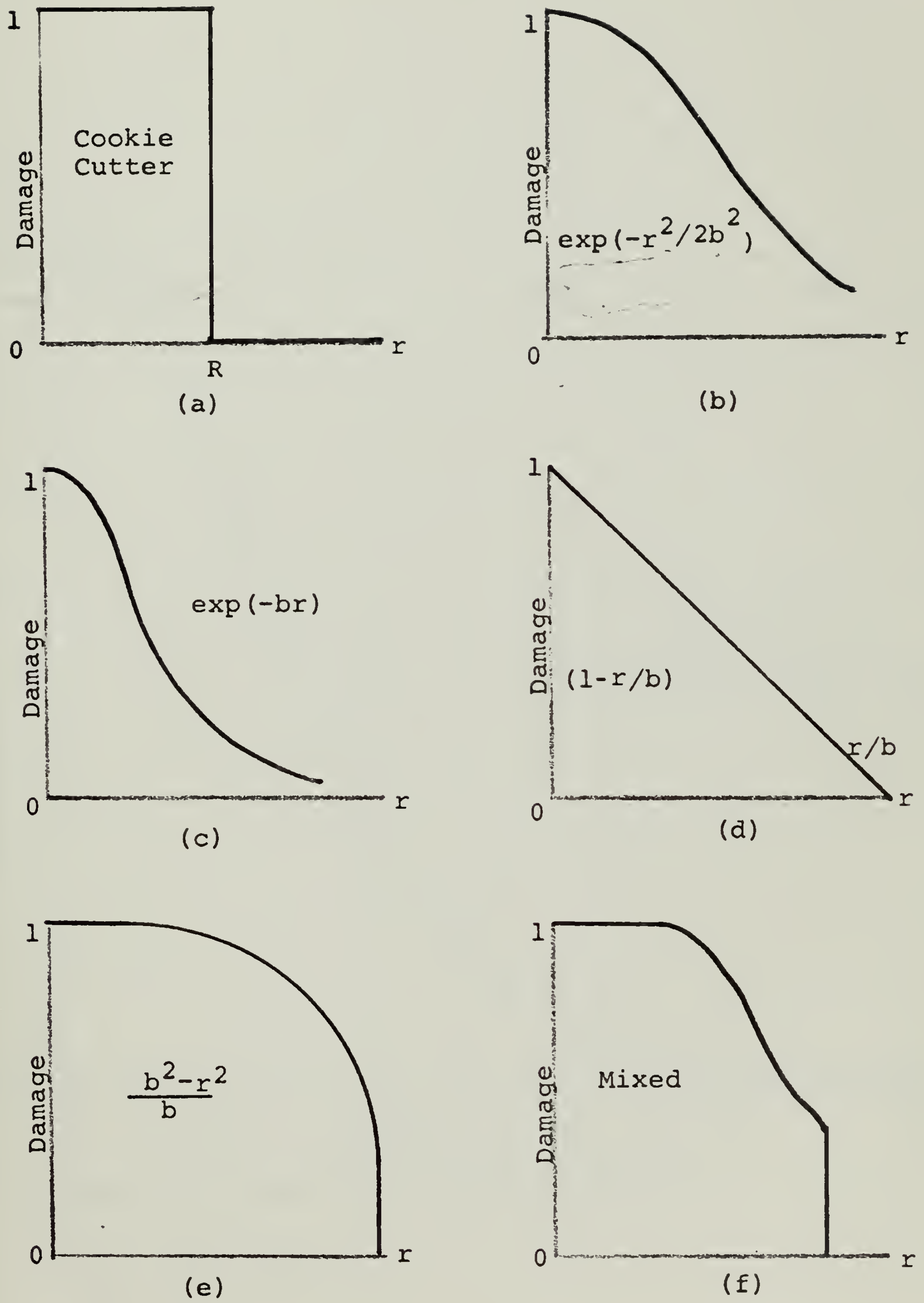


Figure 2. Damage Functions

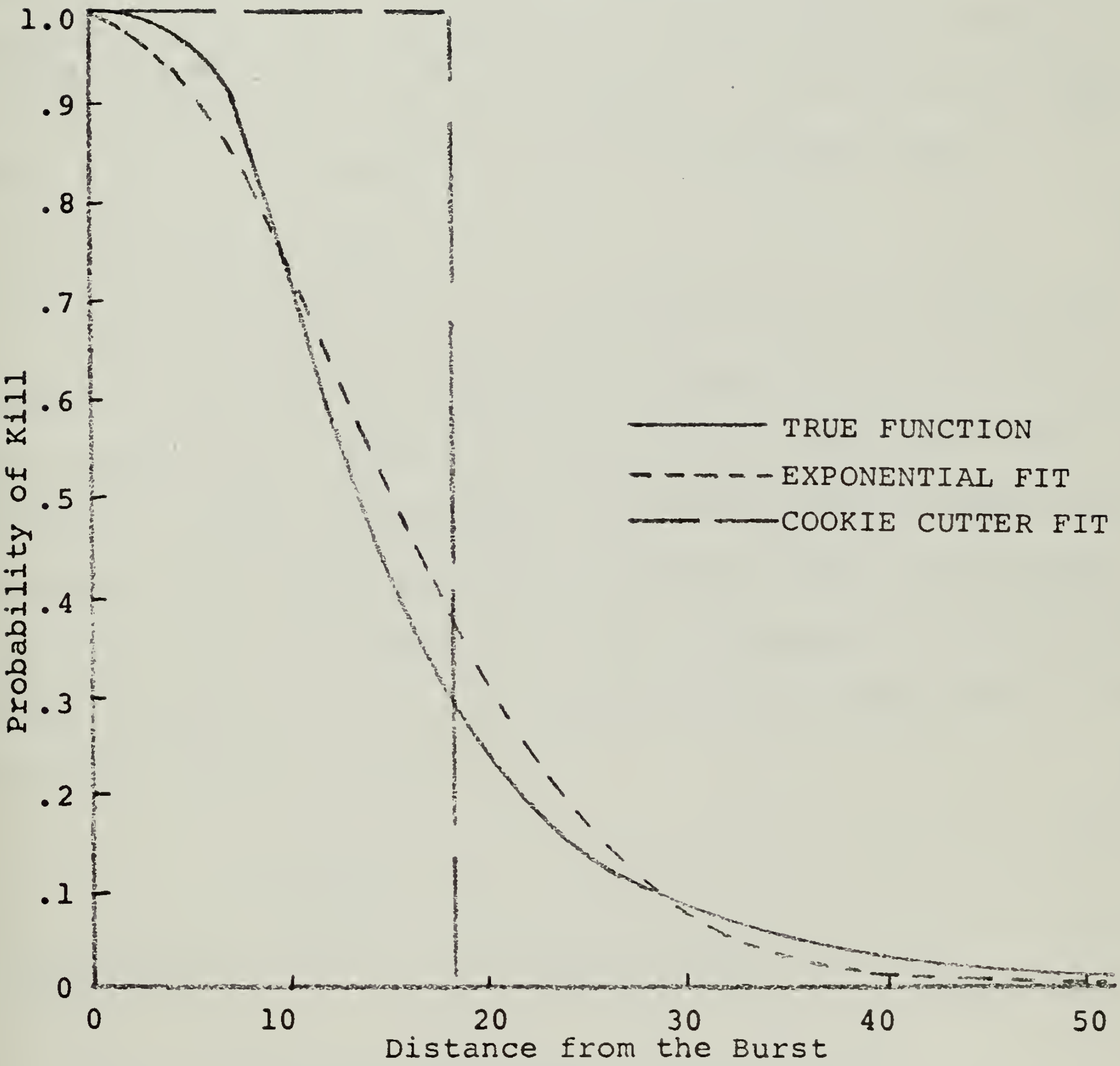


Figure 3. Round Lethality Function

III. THE SALVO MODEL

A. INTRODUCTION

The salvo-fire model is a specific form of the general target coverage model. The conditions of salvo-fire dictate an explicit form for each of the parametric distributions discussed in the last chapter. These explicit forms for one and two dimensional cases are discussed below.

B. ONE DIMENSION CASE

The one dimension model is convenient for conveying the essential features of a salvo-fire model without obscuring its features with unessential details and complicated relationships. Using a rectangular coordinate system (see Fig. 4) with the target reference point located at x=0, the assumed aim point is at some point x_a. This distance is a measure of target location error or alternatively, of aiming error. The ith round impacts at x_{b_i}.

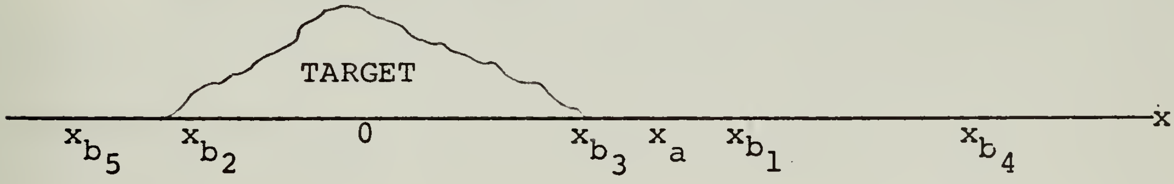


Figure 4. 1D Target Coverage Model.

1. Specific Assumptions

a. Target Location Error

x_a is distributed normally with mean μ_a and variance σ_a^2 so that,

$$f(x_a) = \frac{1}{\sigma_a\sqrt{2\pi}} \exp\left[-\frac{1}{2}\left(\frac{x_a-\mu_a}{\sigma_a}\right)^2\right]$$

b. Ballistic Error

x_b is distributed normally with mean x_a and variance σ_b^2 so that

$$f(x_b) = \frac{1}{\sigma_b\sqrt{2\pi}} \exp\left[-\frac{1}{2}\left(\frac{x_b-x_a}{\sigma_b}\right)^2\right]$$

c. Damage Function

The functional form for the damage function is the exponential function,

$$\underline{d}(x) = \exp\left(-\frac{x^2}{2a^2}\right)$$

where a is a shape parameter derived from a fit to experimental lethality data which has been independently determined from fragmentation tests or other techniques and is called the lethal radius. "x" is the distance from center of impact.

2. <u>The Analytical Model</u> [15]

Under these assumptions the conditional probability of killing the target with one round given that the aim point is x_a, denoted by P_{k/x_a}, is,

$$\int_{-\infty}^{\infty} \frac{1}{\sigma_b\sqrt{2\pi}} \exp\left[-\frac{1}{2}\left(\frac{x_b-x_a}{\sigma_b}\right)^2\right] \exp\left(-\frac{x_b^2}{2a^2}\right) dx_b$$

$$= \frac{a}{\sqrt{a^2+\sigma_b^2}} \exp\left(-\frac{x_a^2}{2(a^2+\sigma_b^2)}\right).$$

Considering the firing of N rounds at an aim point and then averaging over a distribution of aim points, the result is,

$$PK_N = 1 - \int_{-\infty}^{\infty} (1-P_{K/x_a})^N f_{x_a}(x_a)\, dx_a$$

$$= a \sum_{K=1}^{N} \binom{N}{K} \left(\frac{-a}{\sqrt{a^2+\sigma_b^2}} \right)^{K-1} \frac{\exp\left(\frac{-K\mu_a^2}{2(a^2+\sigma_b^2+K\sigma_a^2)} \right)}{\sqrt{a^2+\sigma_b^2+K\sigma_a^2}}$$

If the assumption is made that the effects of rounds are statistically independent then the independent model is,

$$PK^*_N = 1 - (1-PK_1)^N .$$

The computer program used to calculate the values of PK_N, PK^*_N, $PK^*_N-PK_N$ (absolute difference) and $\frac{PK^*_N-PK_N}{PK_N}$ (relative difference) for N=1 to 15 is given as Appendix A. The inputs for this program are "a", μ_a, σ_a, and σ_b. Values for these inputs were determined as follows.

a. Lethal Radius

No attempt was made to fit "a" to experimental lethality functions nor to determine "a" from classified lethality data. As used in this study it was the radius of burst obtained by subtracting the width of an open sheaf from the front of an open sheaf as shown in FM 6-40 [4] and dividing by two. (See Fig. 5.) Approximate "a" derived in this manner for various weapons is shown in Table I.

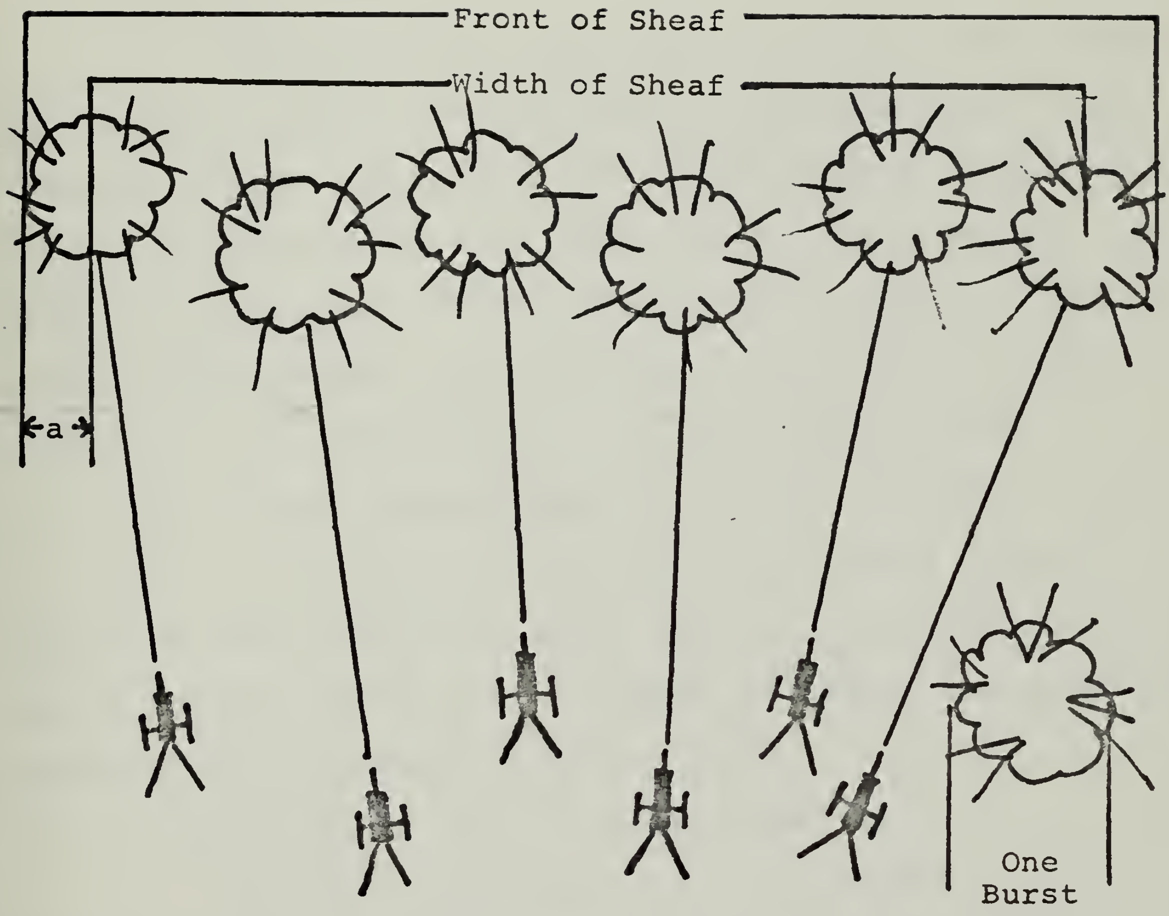


Figure 5. Lethal Radius.

TABLE I

"a" FOR VARIOUS WEAPONS

Weapon	a(meters)
105 mm	15
155 mm	25
175 mm	47.5
8 inch	40

b. Mean Aim Point

Experiment 31.1 [16] showed that the mean target location error among forward observers under daylight conditions using nine target types, two environmental conditions, and over various ranges was -167 meters in range and 28 meters in deflection. For particular combinations of environment and targets, mean range error was as much as -407 meters and mean deflection error as much as 72 meters.

c. Target Location Error Standard Deviation

A supplement to experiment 31.1 gave probable errors for three types of target location techniques and three range bands (see Table II). Standard deviation was determined by dividing the probable error by .6745.

d. Ballistic Error Standard Deviation

This data was extracted from standard artillery firing tables [5, 6, 7,. 8] and is displayed in Table III.

3. Comparison of Independent and Dependent Models

The computer program used to calculate values of PK_N and PK^*_N also calculated the absolute difference $PK^*_N-PK_N$ and the relative difference $(PK^*_N-PK_N)/PK_N$. While the absolute difference may have been small, reflecting small values of PK_N and PK^*_N , the relative difference may have been quite large.

To determine the effect on model differences of various values of the input variables, each was in turn varied over a range and the others held constant at a base value. These base values were $a=20$, $\mu_a=50$, $\sigma_b=20$ and $\sigma_a=20$ and were

TABLE II

TARGET LOCATION ERROR STANDARD DEVIATIONS

Target Location Technique	Range (meters)	Probable Error (meters)	Standard Deviation (meters)
Polar	< 2000	r 165 d 27	245 40
	2000 to 4000	r 480 d 27	712 40
	> 4000	r 800 d 27	1186 40
Grid	< 2000	r 110 d 64	163 95
	2000 to 4000	r 525 d 64	778 95
	> 4000	r 922 d 64	1367 95
Shift	< 2000	r 135 d 101	200 150
	2000 to 4000	r 830 d 203	1231 301
	> 4000	r 1850 d 200	2743 297

TABLE III

BALLISTIC ERROR STANDARD DEVIATIONS

Weapon	Range (meters)	Probable Error (meters)	Standard Deviation (meters)
105mm Howitzer	2500	r 8	12
		d 1	1.5
	5000	r 11	16
		d 3	4.5
	7500	r 14	21
		d 5	7.5
	10,000	r 19	28
		d 7	10
155mm Howitzer	5000	r 11	16
		d 2	3
	10,000	r 27	40
		d 4	6
	15,000	r 40	59
		d 4	6
8 inch Howitzer	5000	r 13	19
		d 3	4.5
	10,000	r 26	39
		d 5	7.5
	14,500	r 38	56
		d 10	15
175mm Gun	5000	r 16	24
		d 2	3
	10,000	r 20	30
		d 5	7.5
	20,000	r 35	52
		d 10	15
	30,000	r 63	93
		d 17	25

selected so that they would be representative and so that probabilities of kill would vary over most of their 0-1 range. Figures 6 - 9 illustrate the relative model difference as a function of the number of rounds fired. Note that the vertical scales vary.

Relative difference plotted against N was in all cases an initially increasing function. This occurred as a result of model equality for N=1 and the fact that $PK_N^* \geq PK_N$ for all N. When the probabilities of kill approached their limiting values of zero or one, absolute difference decreased causing a decrease in relative difference. This resulted in a curve which initially increased then decreased as the probabilities of kill got close to one.

An analysis of the curves plotted in Figures 6 - 9 resulted in the general observation that relative difference increased as N increased for small probabilities of kill. It was therefore expected that relative difference would increase if factors that caused a degeneration in probability of kill were increased. This was reflected in Fig. 6 which showed that relative difference increased as lethal radius decreased. Figure 7 showed an increase in relative difference for an increase in mean aim point until the mean aim point was so far off target that the probabilities of kill approached zero. Relative difference increased as ballistic error decreased which at first looked like a contradition to the premise that relative difference would increase as degenerative factors were increased. However, further analysis showed that increased

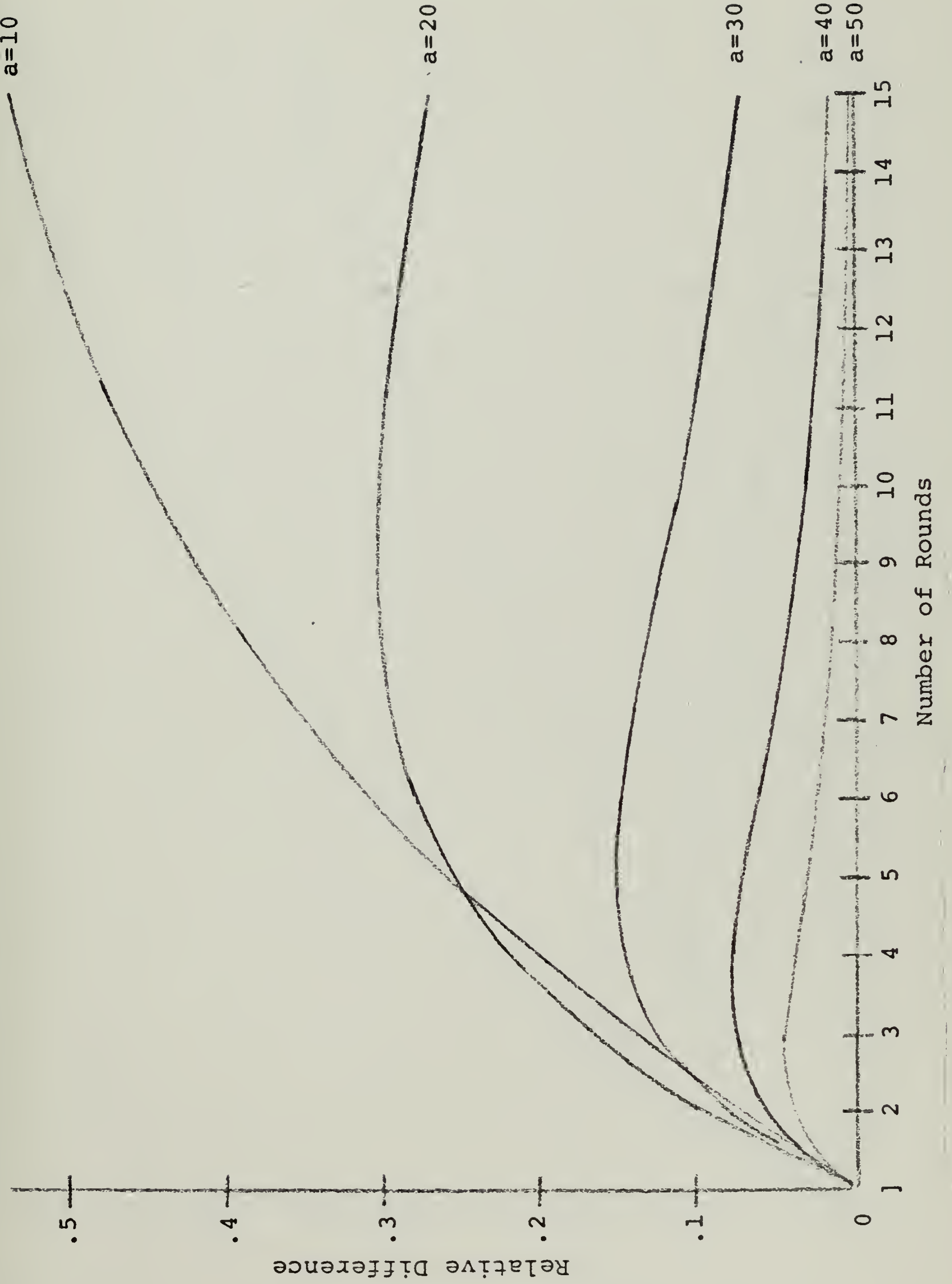


Figure 6. 1D Relative Difference for "a"

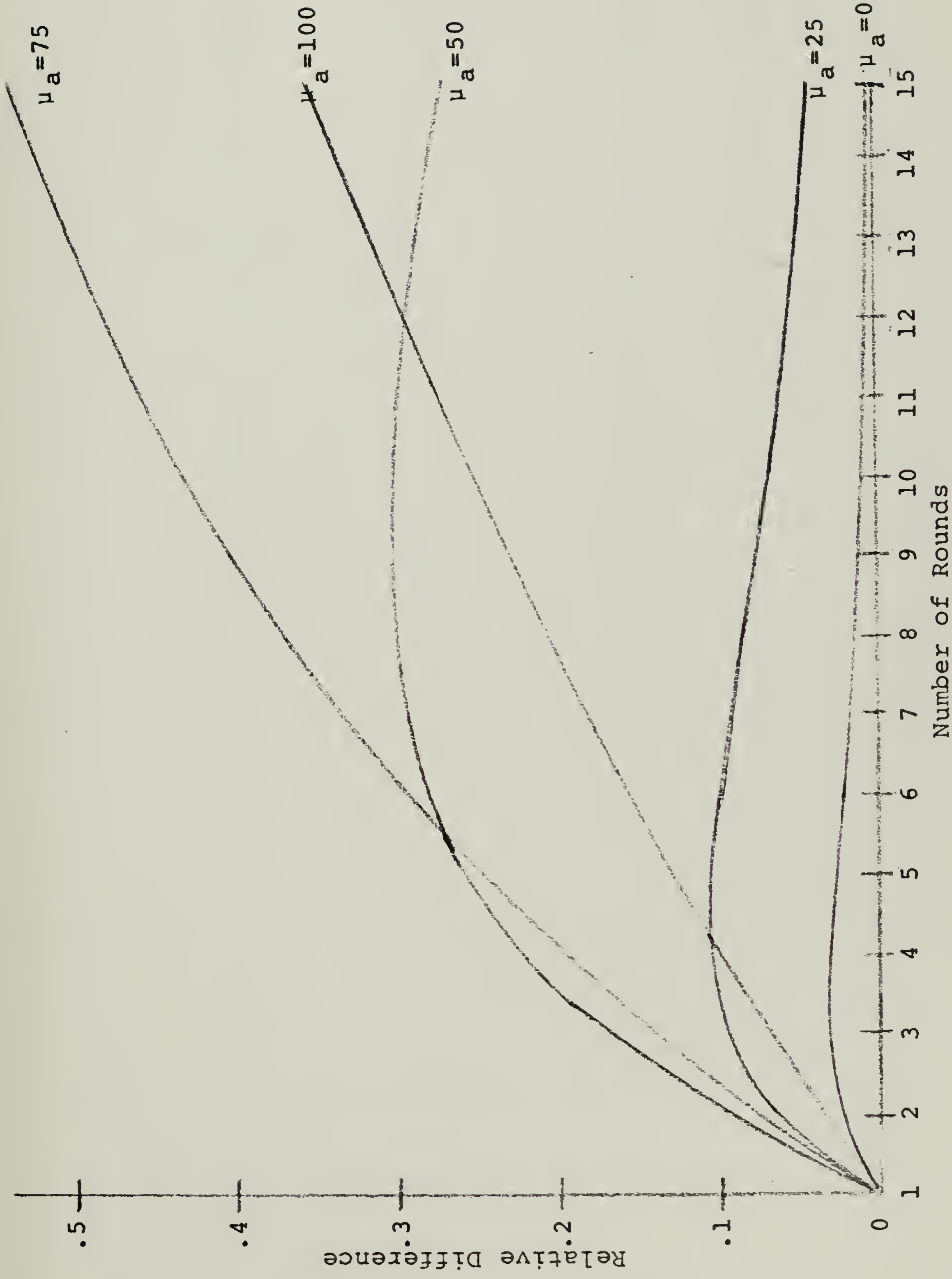


Figure 7. 1D Relative Difference for μ_a

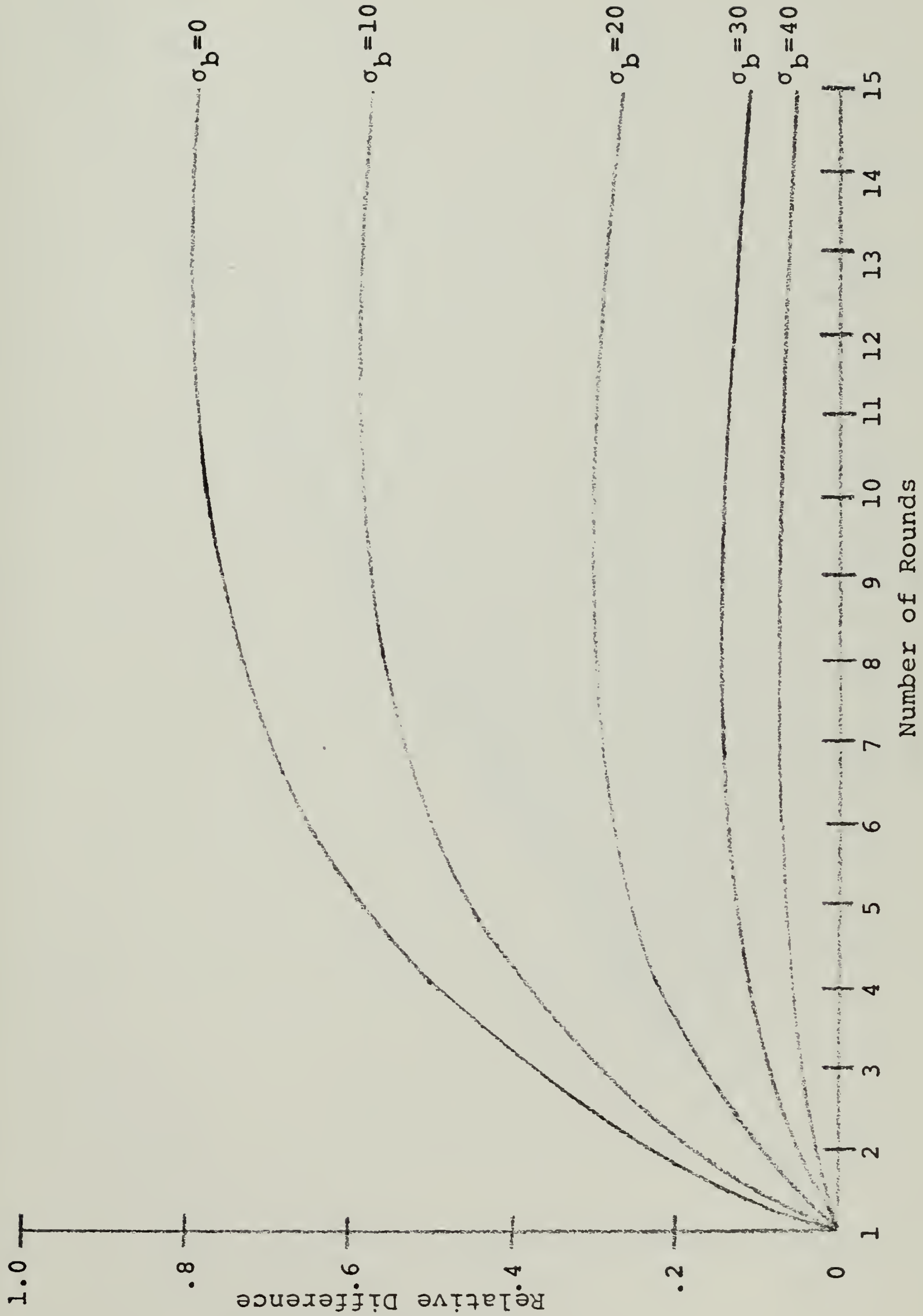


Figure 8. 1D Relative Difference for σ_b

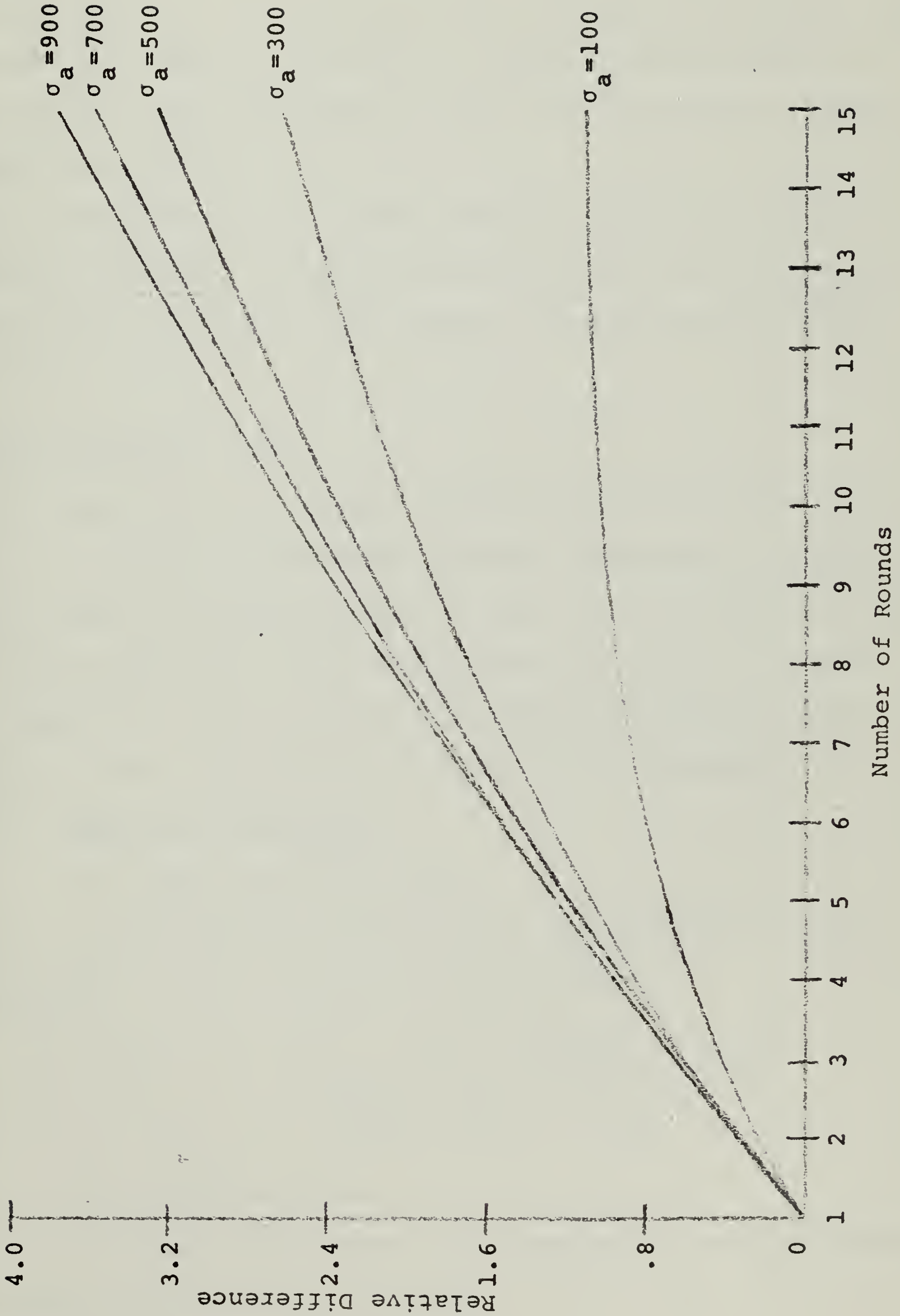


Figure 9. 1D Relative Difference for σ_a

ballistic error caused increased probability of kill due to the fact that the aim point was quite far from the target. An increase in dispersion resulted in rounds landing further from the aim point but closer to the target, giving a greater probability of kill.

The premise was further reinforced by Fig. 9 which showed an increase in relative difference as the distribution of aim errors flattened out, causing a degeneration in probabilities of kill.

C. TWO DIMENSION CASE

The addition of a second dimension brought the model much closer to reality and provided a method for getting answers to the target coverage problem in real would situations. Both range and deflection errors were taken into account so that the functional forms of error distributions were bivariate. Results of the calculations are included as Appendix A.

1. Specific Assumptions

a. Target Location Error

The target location error was assumed to be uncorrelated bivariate circular normal so that,

$$\underline{\ell}(U,V;u,v) = \frac{1}{2\pi\sigma_a^2}\exp\left[-\frac{(u-U)^2+(v-V)^2}{2\sigma_a^2}\right]$$

b. Ballistic Error

The ballistic error was assumed to be uncorrelated bivariate circular normal so that,

$$\underline{b}(x,y;\bar{x},\bar{y}) = \frac{1}{2\pi\sigma_b^2} \exp\left[- \frac{(x-\bar{x})^2 + (y-\bar{y})^2}{2\sigma_b^2} \right]$$

c. Target Density

The target was assumed to have a value of one and was assumed to be distributed over the area it occupied according to an uncorrelated bivariate circular normal distribution about the target centroid so that,

$$\underline{w}(p,q;u,v) = \frac{1}{2\pi\sigma_t^2} \exp\left[- \frac{(p^2+q^2)}{2\sigma_t^2} \right]$$

d. Damage (Lethality)

The damage function had the form of an exponential damage function so that,

$$\underline{d}(p,q;x,y) = \exp\left(- \frac{1}{2} \left[\frac{(p-x)^2 + (q,y)^2}{a^2} \right] \right)$$

e. Bias (Offset)

This model assumed that there was no bias.

2. <u>The Analytical Model</u> [15]

Under these assumptions the probability of killing the target with one round denoted by $p_{k/\bar{x},\bar{y}}$ is,

$$\frac{a^2}{(a^2+\sigma_b^2)} \left(- \frac{1}{2} \left[\frac{(u-\bar{x})^2 + (v-\bar{y})^2}{a^2 + \sigma_b^2} \right] \right)$$

Now considering target density and averaging over all aim points,

$$\overline{F}_N = \int\int\int\int_{-\infty}^{\infty} \underline{w}(p,q;u,v)\,\underline{l}(U,V;u,v) \left(1- \left[1-p_{k/\overline{x},\overline{y}}\right]^N\right) dpdqdUdV$$

$$= Q \sum_{K=1}^{N} \binom{N}{K} \left(-1\right)^{K-1} \frac{P^K}{(Q+K)} \quad \text{where } P = \frac{a^2}{a^2+\sigma_b^2} \text{ and } Q = \frac{a^2+\sigma_b^2}{\sigma_a^2+\sigma_t^2}$$

If the assumption is made that rounds are statistically independent then the independent model is,

$$\overline{F}^*_N = 1-(1-\overline{F}_1)^N$$

The computer program used to calculate AFTK for both independent and dependent models, absolute difference and relative difference is given as Appendix D. The inputs for this program are "a", σ_a, σ_b and σ_t. Values for these inputs were determined as follows.

a. Lethal Radius

The lethal radius was determined as for the one dimension case.

b. Target Density Standard Deviation

A typical small target for artillery weapons is an infantry platoon in a defensive perimeter. Consider a platoon of about 40 men configured in a circular defensive perimeter with 10 three-man foxholes two meters wide on the perimeter with 10 meters between foxholes. If the target has about 95% of its value normally distributed on and within the perimeter (there may be listening posts outside the perimeter) then the radius of the defensive position which is approximately 20 meters would be at two standard deviations. Therefore, a standard deviation of 10 meters would be a good approximation for a small target.

c. Target Location Error Standard Deviation

This value is determined from Experiment 31.1 as outlined in the one dimension case.

d. Ballistic Error Standard Deviation

This data was extracted from standard artillery firing tables [5, 6, 7, 8] and is displayed in Table III.

3. Comparison of Independent and Dependent Models

Figures 10 - 13 illustrate the relative model difference as a function of the number of rounds fired. Note that the vertical scales vary.

D. APPLICATION TO SPECIFIC WEAPONS SYSTEMS

The model could be used to calculate AFTK for specific weapons systems if certain of the assumptions for the two dimension case were changed to conform to actual distributions for the various inputs. This was accomplished by assuming non-correlated bivariate elliptical normal distributions and allowing for bias. Inputs for this model were taken from actual data if available and estimated if not available. An exception was the lethal radius "a" for various weapons. It was determined as for the one dimension case and was not based on classified lethality data which was available. Results of the calculations are included as Appendix B.

1. Specific Assumptions

a. Target Location Error

The target location error was assumed to be uncorrelated bivariate elliptical normal so that,

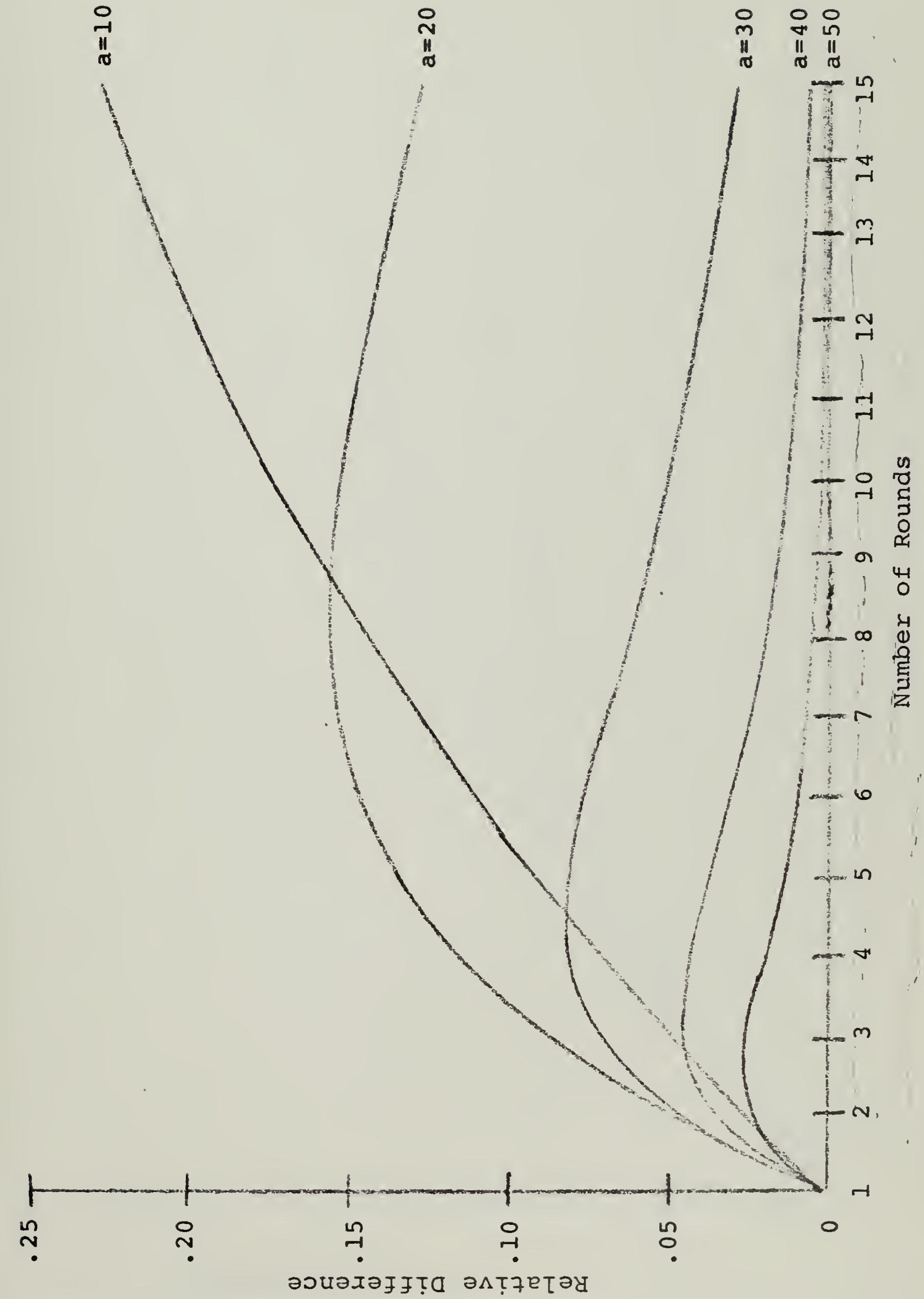


Figure 10. 2D Relative Difference for "a"

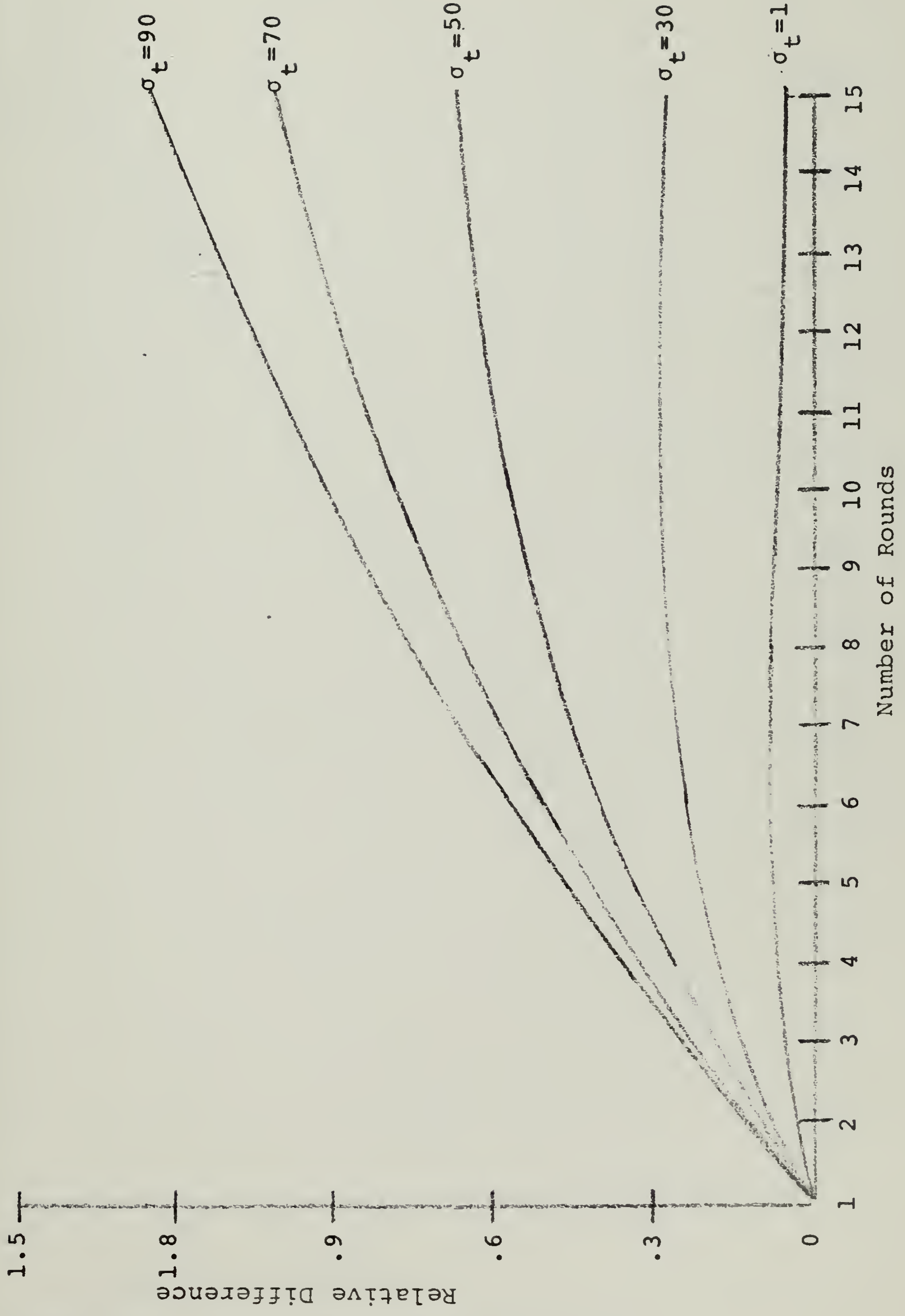


Figure 11. 2D Relative Difference for σ_t

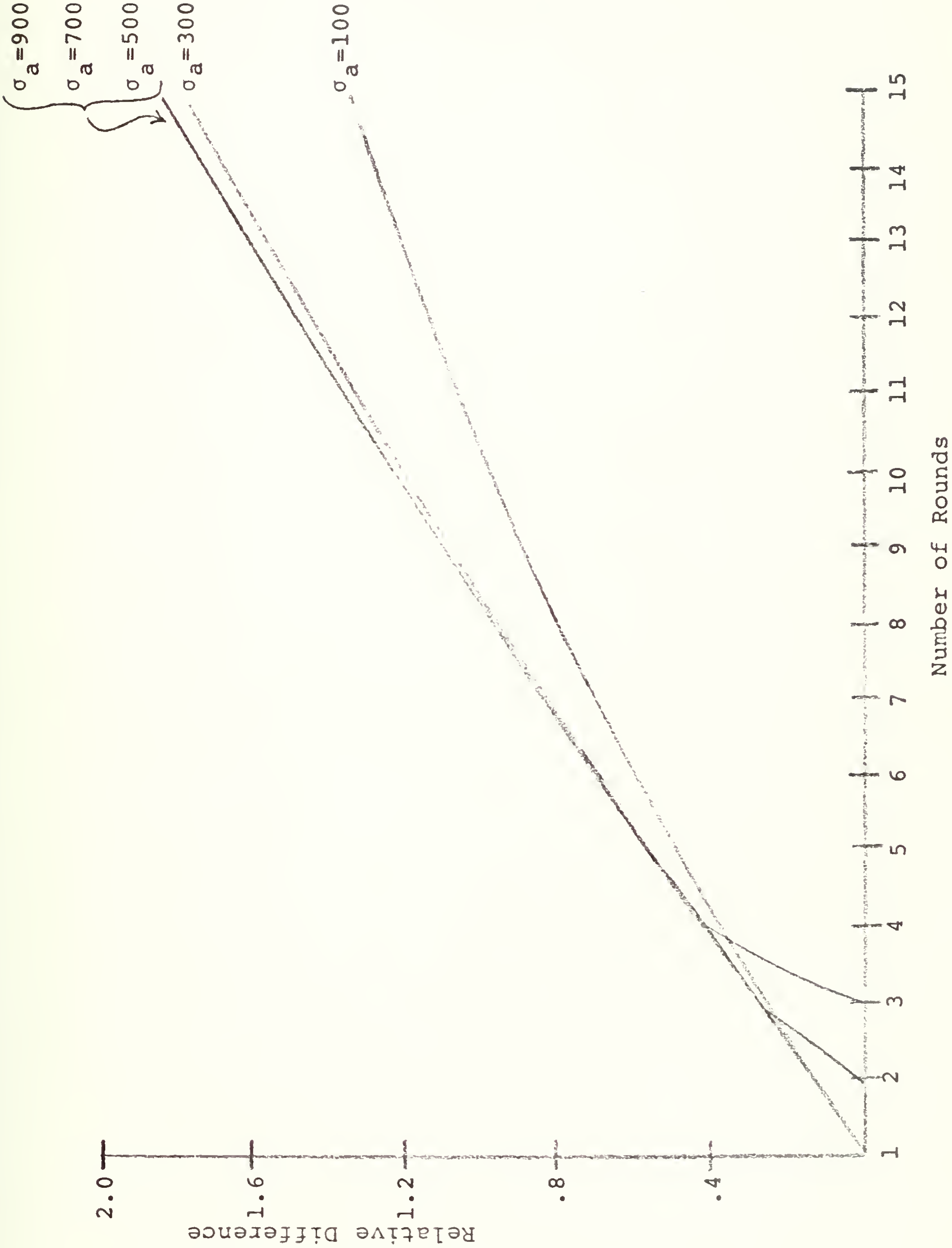


Figure 12. 2D Relative Difference for σ_a

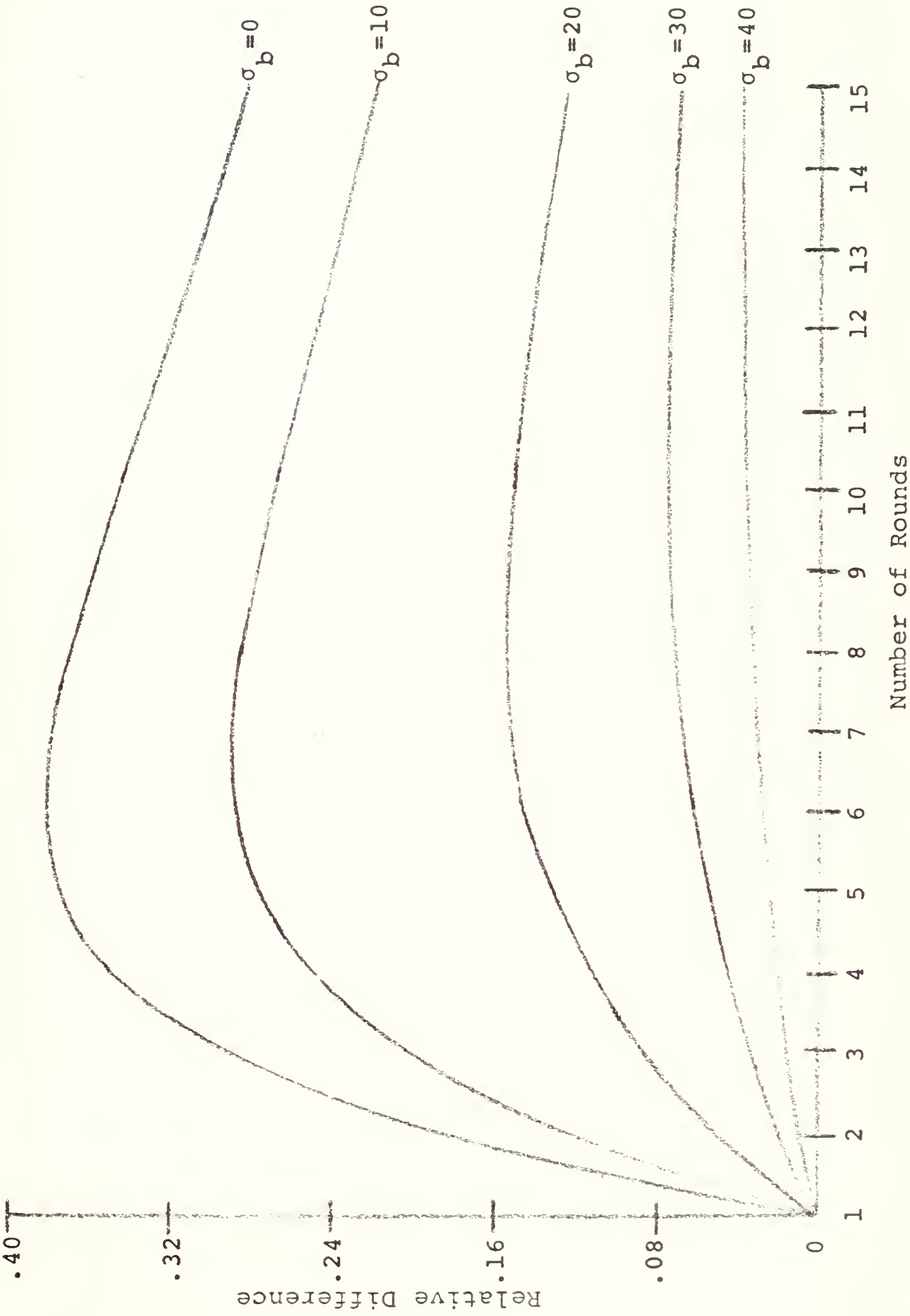


Figure 13. 2D Relative Difference for σ_b

$$\underline{\ell}(U,V;u,v) = \frac{1}{2\pi\sigma_{a_x}\sigma_{a_y}} \exp\left(-\frac{1}{2}\left[\frac{(U-u)^2}{\sigma_{a_x}^2} + \frac{(V-v)^2}{\sigma_{a_y}^2}\right]\right)$$

b. Ballistic Error

The ballistic error was assumed to be uncorrelated bivariate elliptical normal so that

$$\underline{b}(x,y;\bar{x},\bar{y}) = \frac{1}{2\pi\sigma_{b_x}\sigma_{b_y}} \exp\left(-\frac{1}{2}\left[\frac{(x-\bar{x})^2}{\sigma_{b_x}^2} + \frac{(y-\bar{y})^2}{\sigma_{b_y}^2}\right]\right)$$

c. Target Density

The target was assumed to have a value of one and to be distributed as an uncorrelated bivariate elliptical normal distribution so that,

$$\underline{w}(p,q;u,v) = \frac{1}{2\pi\sigma_{t_x}\sigma_{t_y}} \exp\left(-\frac{1}{2}\left[\frac{(p-u)^2}{\sigma_{t_x}^2} + \frac{(q-v)^2}{\sigma_{t_y}^2}\right]\right)$$

d. Damage (Lethality)

The damage function was given the form of an uncorrelated bivariate elliptical normal distribution so that,

$$\underline{d}(p,q;x,y) = \frac{1}{2\pi a_x a_y} \exp\left(-\frac{1}{2}\left[\frac{(p-x)^2}{a_x^2} + \frac{(q-y)^2}{a_y^2}\right]\right)$$

e. Bias

Bias was allowed.

2. <u>The Analytical Model</u> [9, 15]

Under these assumptions,

$$\overline{F}_N = \sqrt{q_x q_y} \sum_{K=1}^{N} \binom{N}{K} (-1)^{K-1} \frac{\left(\sqrt{p_x p_y}\right)^K}{\sqrt{(q_x+K)(q_y+K)}} \quad \text{where,}$$

$$p_x = \frac{a_x^{\,2}}{a_x^{\,2} + \sigma_{b_x}^{\,2}}, \quad q_x = \frac{a_x^{\,2} + \sigma_{b_x}^{\,2}}{\sigma_{t_x}^{\,2} + \sigma_{a_x}^{\,2}}$$

$$p_y = \frac{a_y^{\,2}}{a_y^{\,2} + \sigma_{b_y}^{\,2}}, \quad q_y = \frac{a_y^{\,2} + \sigma_{b_y}^{\,2}}{\sigma_{t_y}^{\,2} + \sigma_{a_y}^{\,2}}$$

and $\overline{F}_N^{*}=1-(1-\overline{F}_1)^N$ for statistically independent rounds. Values for the inputs required in the computer program for this model were determined as follows.

a. Lethal Radius

In reality a_x and a_y depend on the angle of fall of the projectile which in turn depends on the trajectory of the round. Generally angle of fall will increase then decrease with range. The values for a_x and a_y could be accurately determined from angle of fall data contained in firing tables and classified lethality data. However, in this program these values were determined as outlined in the one dimension case so that for the 105mm howitzer, for instance, $a_x=a_y=15$.

b. Target Location Error Standard Deviation

These values were extracted from Table II for three representative ranges for each weapon.

c. Ballistic Error Standard Deviations

These values were extracted from Table III for the grid method.

d. Bias

The target used for the specific weapons case was target Type F from Experiment 31.1 [16]. Target Type F consisted of 24 men stationary in a defensive formation with half the personnel simulating digging in. Values for U and V, the mean target location errors for range and deflection respectively, were taken from Experiment 31.1 for data based on target Type F. These values were U=-158 meters and V=32 meters which was an average over all observer-target ranges.

e. Target Density Function Standard Deviations

These values were determined for target Type F by the method outlined in the two dimensional case of a platoon in a defensive perimeter, giving a radius of 16.6 meters and a target density standard deviation of 8.3 meters.

3. Comparison of Independent and Dependent Models

Appendix B gives tables of average fraction of target killed for the case of specific weapons. The tables show that when in the artillery operation N rounds are fired and elliptical distributions and representative data are used, the error resulting from the independence of effects of rounds assumption is greater than 300% in some cases. The error was large enough to conclude that studies based on this simplifying assumption may lead to erroneous conclusions. This was perhaps the situation in the MAF Fire Support Study mentioned in the introduction. In that study ordnance expenditures required to achieve a specific level of destruction of area targets were computed [13] by,

$$N=\ln(1-K)/\ln(1-E(C))$$

where:

N = the average number of rounds required to achieve the desired level of destruction of the target,

K = the level of destruction required,

$E(C)$ = the average fraction of target killed from the delivery of one round (called $\overline{F}_1$ in this paper).

Multiplying both sides of the above equation by $\ln(1-E(C))$ gives

$$N \ln(1-E(C))=\ln(1-K)$$

$$\text{or} \quad \ln(1-E(C))^N=\ln(1-K)$$

$$\text{or} \quad (1-E(C))^N=1-K$$

$$\text{or} \quad K=1-(1-E(C))^N$$

which is the independent model developed in this paper.

The MAF study used the Simplified Weapons Evaluation Model (SWEM) [14] to determine E(C)'s for the various target-weapon coverage problems encountered in that study. The SWEM model is very general and has the capability of calculating the average fraction of target killed without making the independence assumption. In order for the MAF study to use the independence assumption, it would have been necessary to calculate $\overline{F}_1$ using the SWEM model and then apply the formula $K=1-(1-\overline{F}_1)^N$. This procedure does not use the SWEM model to its full capability and results in errors, the size of which depend on the specific inputs into the model.

IV. CONCLUSION

There was a significant difference between the results of computations with the model in which it is assumed that the effects of rounds are independent and the standard salvo-fire model. In some cases this difference was more than 300% and was usually greater than 200% for the two dimension model in which elliptical normal distributions and representative input data were used. Hence it is concluded that the model which assumes statistical independence of effects of rounds is a very poor approximation to the salvo-fire model.

Analysts performing studies on weapons system design, stockpiling ammunition, cost analysis, and related target coverage studies should be aware of the limitations of simplified target coverage models (such as the independence of effects model for the firing of N rounds). The use of such simplified models should be justified by representative calculations to determine the amount of disparity between them and the more sophisticated models. Otherwise, large errors in average fraction of target killed may result.

Future analysis on the subject material covered in this thesis might include (1) model verification and more accurate comparisons based on classified lethality data; (2) extension of the target coverage model to battery firing; (3) comparisons of other than salvo-fire target coverage models with simplified models; and (4) the use of such target coverage models to investigate artillery tactics.

APPENDIX A

COMPUTER OUTPUT FOR 2D MODEL

These tables contain values for N, the number of rounds fired in the salvo, AFTK, the average fraction of target killed for the dependent model, AFTK(INDEP), the average fraction of target killed for the independent model, DIFF(ABSOLUTE), the absolute difference, and DIFF(RELATIVE), the relative difference.

Inputs have the following values.

$N=(1,15)1$

$a=(10,50)20$

$\sigma_t=(10,210)100$

$\sigma_a=(0,400)200$

$\sigma_b=(0,60)30$

The tables contain computations for all 1215 combinations of the above inputs. See APPENDIX D for the computer program.

```
LETHAL RADIUS=   10.0
TARGET DENSITY VARIANCE=       100.0
TARGET LOCATION ERROR VARIANCE=          0.0
BALLISTIC ERROR VARIANCE=         0.0

N        AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1       0.500       0.500          0.0               0.0
 2       0.667       0.750          0.083             0.125
 3       0.750       0.875          0.125             0.167
 4       0.800       0.938          0.137             0.172
 5       0.833       0.969          0.135             0.162
 6       0.857       0.984          0.127             0.148
 7       0.875       0.992          0.117             0.134
 8       0.889       0.996          0.107             0.121
 9       0.900       0.998          0.098             0.109
10       0.909       0.999          0.090             0.099
11       0.917       1.000          0.083             0.090
12       0.923       1.000          0.077             0.083
13       0.929       1.000          0.071             0.077
14       0.933       1.000          0.067             0.071
15       0.937       1.000          0.062             0.067


LETHAL RADIUS=   10.0
TARGET DENSITY VARIANCE=       100.0
TARGET LOCATION ERROR VARIANCE=          0.0
BALLISTIC ERROR VARIANCE=       900.0

N        AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1       0.091       0.091          0.0               0.0
 2       0.173       0.174          0.0               0.0
 3       0.248       0.249          0.0               0.0
 4       0.317       0.317          0.0               0.0
 5       0.379       0.379          0.001             0.001
 6       0.435       0.436          0.001             0.002
 7       0.486       0.487          0.001             0.002
 8       0.532       0.533          0.001             0.002
 9       0.575       0.576          0.001             0.002
10       0.613       0.614          0.002             0.002
11       0.648       0.650          0.002             0.003
12       0.680       0.681          0.002             0.003
13       0.708       0.710          0.002             0.003
14       0.735       0.737          0.002             0.003
15       0.758       0.761          0.002             0.003


LETHAL RADIUS=   10.0
TARGET DENSITY VARIANCE=       100.0
TARGET LOCATION ERROR VARIANCE=          0.0
BALLISTIC ERROR VARIANCE=     3600.0

N        AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1       0.026       0.026          0.0               0.0
 2       0.052       0.052          0.0               0.0
 3       0.077       0.077          0.0               0.0
 4       0.101       0.101          0.0               0.0
 5       0.125       0.125          0.0               0.0
 6       0.148       0.148          0.0               0.0
 7       0.170       0.170          0.0               0.0
 8       0.192       0.192          0.0               0.0
 9       0.213       0.213          0.0               0.0
10       0.234       0.234          0.0               0.0
11       0.254       0.254          0.0               0.0
12       0.274       0.274          0.0               0.0
13       0.293       0.293          0.0               0.0
14       0.312       0.312          0.0               0.0
15       0.330       0.330          0.0               0.0
```

```
LETHAL RADIUS=    10.0
TARGET DENSITY VARIANCE=       100.0
TARGET LOCATION ERROR VARIANCE=    40000.0
BALLISTIC ERROR VARIANCE=        0.0

N        AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1       0.002       0.002           0.0                0.0
 2       0.004       0.005           0.001              0.332
 3       0.005       0.007           0.003              0.633
 4       0.005       0.010           0.005              0.915
 5       0.006       0.012           0.007              1.181
 6       0.006       0.015           0.009              1.437
 7       0.006       0.017           0.011              1.684
 8       0.007       0.020           0.013              1.923
 9       0.007       0.022           0.015              2.155
10       0.007       0.025           0.017              2.382
11       0.007       0.027           0.020              2.604
12       0.008       0.029           0.022              2.822
13       0.008       0.032           0.024              3.036
14       0.008       0.034           0.026              3.246
15       0.008       0.037           0.028              3.453
```

```
LETHAL RADIUS=    10.0
TARGET DENSITY VARIANCE=       100.0
TARGET LOCATION ERROR VARIANCE=    40000.0
BALLISTIC ERROR VARIANCE=      900.0

N        AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1       0.002       0.002           0.0                0.0
 2       0.005       0.005           0.0                0.0
 3       0.007       0.007           0.0                0.0
 4       0.009       0.010           0.001              0.074
 5       0.011       0.012           0.001              0.099
 6       0.013       0.015           0.002              0.124
 7       0.015       0.017           0.002              0.149
 8       0.016       0.019           0.003              0.174
 9       0.018       0.022           0.004              0.199
10       0.020       0.024           0.004              0.224
11       0.021       0.026           0.005              0.249
12       0.023       0.029           0.006              0.274
13       0.024       0.031           0.007              0.299
14       0.025       0.034           0.008              0.324
15       0.027       0.036           0.009              0.349
```

```
LETHAL RADIUS=    10.0
TARGET DENSITY VARIANCE=       100.0
TARGET LOCATION ERROR VARIANCE=    40000.0
BALLISTIC ERROR VARIANCE=     3600.0

N        AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1       0.002       0.002           0.0                0.0
 2       0.005       0.005           0.0                0.0
 3       0.007       0.007           0.0                0.0
 4       0.009       0.009           0.0                0.0
 5       0.011       0.011           0.0                0.0
 6       0.013       0.014           0.0                0.0
 7       0.015       0.016           0.001              0.036
 8       0.017       0.018           0.001              0.042
 9       0.019       0.020           0.001              0.048
10       0.021       0.023           0.001              0.054
11       0.023       0.025           0.001              0.059
12       0.025       0.027           0.002              0.065
13       0.027       0.029           0.002              0.071
14       0.029       0.031           0.002              0.077
15       0.031       0.034           0.003              0.083
```

```
LETHAL RADIUS=   10.0
TARGET DENSITY VARIANCE=      100.0
TARGET LOCATION ERROR VARIANCE=  160000.0
BALLISTIC ERROR VARIANCE=         0.0

N        AFTK      AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1       0.001        0.001          0.0                0.0
 2       0.001        0.001          0.0                0.0
 3       0.001        0.002          0.001              0.636
 4       0.001        0.002          0.001              0.919
 5       0.001        0.003          0.002              1.188
 6       0.002        0.004          0.002              1.446
 7       0.002        0.004          0.003              1.696
 8       0.002        0.005          0.003              1.938
 9       0.002        0.006          0.004              2.175
10       0.002        0.006          0.004              2.406
11       0.002        0.007          0.005              2.633
12       0.002        0.007          0.006              2.856
13       0.002        0.008          0.006              3.075
14       0.002        0.009          0.007              3.291
15       0.002        0.009          0.007              3.503
```

```
LETHAL RADIUS=   10.0
TARGET DENSITY VARIANCE=      100.0
TARGET LOCATION ERROR VARIANCE=  160000.0
BALLISTIC ERROR VARIANCE=       900.0

N        AFTK      AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1       0.001        0.001          0.0                0.0
 2       0.001        0.001          0.0                0.0
 3       0.002        0.002          0.0                0.0
 4       0.002        0.002          0.0                0.0
 5       0.003        0.003          0.0                0.0
 6       0.003        0.004          0.0                0.0
 7       0.004        0.004          0.001              0.154
 8       0.004        0.005          0.001              0.180
 9       0.005        0.006          0.001              0.206
10       0.005        0.006          0.001              0.232
11       0.005        0.007          0.001              0.258
12       0.006        0.007          0.002              0.284
13       0.006        0.008          0.002              0.310
14       0.006        0.009          0.002              0.336
15       0.007        0.009          0.002              0.362
```

```
LETHAL RADIUS=   10.0
TARGET DENSITY VARIANCE=      100.0
TARGET LOCATION ERROR VARIANCE=  160000.0
BALLISTIC ERROR VARIANCE=     3600.0

N        AFTK      AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1       0.001        0.001          0.0                0.0
 2       0.001        0.001          0.0                0.0
 3       0.002        0.002          0.0                0.0
 4       0.002        0.002          0.0                0.0
 5       0.003        0.003          0.0                0.0
 6       0.004        0.004          0.0                0.0
 7       0.004        0.004          0.0                0.0
 8       0.005        0.005          0.0                0.0
 9       0.005        0.005          0.0                0.0
10       0.006        0.006          0.0                0.0
11       0.006        0.007          0.0                0.0
12       0.007        0.007          0.0                0.0
13       0.007        0.008          0.001              0.079
14       0.008        0.009          0.001              0.086
15       0.008        0.009          0.001              0.093
```

```
LETHAL RADIUS=   10.0
TARGET DENSITY VARIANCE=   12100.0
TARGET LOCATION ERROR VARIANCE=         0.0
BALLISTIC ERROR VARIANCE=        0.0

N         AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1        0.008        0.008           0.0                0.0
 2        0.012        0.016           0.004              0.330
 3        0.015        0.024           0.009              0.627
 4        0.017        0.032           0.015              0.903
 5        0.019        0.040           0.022              1.162
 6        0.020        0.048           0.028              1.410
 7        0.021        0.056           0.035              1.647
 8        0.022        0.064           0.042              1.876
 9        0.023        0.071           0.048              2.096
10        0.024        0.079           0.055              2.311
11        0.025        0.087           0.062              2.519
12        0.025        0.094           0.069              2.722
13        0.026        0.101           0.076              2.920
14        0.026        0.109           0.082              3.113
15        0.027        0.116           0.089              3.302
```

```
LETHAL RADIUS=   10.0
TARGET DENSITY VARIANCE=   12100.0
TARGET LOCATION ERROR VARIANCE=         0.0
BALLISTIC ERROR VARIANCE=      900.0

N         AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1        0.008        0.008           0.0                0.0
 2        0.015        0.015           0.0                0.0
 3        0.022        0.023           0.001              0.046
 4        0.028        0.030           0.002              0.068
 5        0.034        0.038           0.003              0.091
 6        0.040        0.045           0.005              0.113
 7        0.046        0.052           0.006              0.136
 8        0.051        0.059           0.008              0.159
 9        0.056        0.067           0.010              0.181
10        0.061        0.074           0.012              0.203
11        0.066        0.081           0.015              0.225
12        0.070        0.088           0.017              0.247
13        0.075        0.095           0.020              0.269
14        0.079        0.102           0.023              0.291
15        0.083        0.109           0.026              0.313
```

```
LETHAL RADIUS=   10.0
TARGET DENSITY VARIANCE=   12100.0
TARGET LOCATION ERROR VARIANCE=         0.0
BALLISTIC ERROR VARIANCE=     3600.0

N         AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1        0.006        0.006           0.0                0.0
 2        0.013        0.013           0.0                0.0
 3        0.019        0.019           0.0                0.0
 4        0.025        0.025           0.0                0.0
 5        0.031        0.031           0.001              0.018
 6        0.037        0.037           0.001              0.022
 7        0.042        0.043           0.001              0.027
 8        0.048        0.050           0.002              0.031
 9        0.054        0.056           0.002              0.036
10        0.059        0.062           0.002              0.040
11        0.065        0.067           0.003              0.045
12        0.070        0.073           0.003              0.049
13        0.075        0.079           0.004              0.053
14        0.080        0.085           0.005              0.058
15        0.086        0.091           0.005              0.062
```

```
LETHAL RADIUS=   10.0
TARGET DENSITY VARIANCE=   12100.0
TARGET LOCATION ERROR VARIANCE=   40000.0
BALLISTIC ERROR VARIANCE=        0.0

N       AFTK     AFTK(INDEP)   DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1      0.002      0.002          0.0               0.0
 2      0.003      0.004          0.001             0.332
 3      0.004      0.006          0.002             0.634
 4      0.004      0.008          0.004             0.916
 5      0.004      0.010          0.005             1.183
 6      0.005      0.011          0.007             1.440
 7      0.005      0.013          0.008             1.687
 8      0.005      0.015          0.010             1.927
 9      0.005      0.017          0.012             2.161
10      0.006      0.019          0.013             2.390
11      0.006      0.021          0.015             2.613
12      0.006      0.023          0.017             2.832
13      0.006      0.025          0.019             3.048
14      0.006      0.026          0.020             3.260
15      0.006      0.028          0.022             3.468
```

```
LETHAL RADIUS=   10.0
TARGET DENSITY VARIANCE=   12100.0
TARGET LOCATION ERROR VARIANCE=   40000.0
BALLISTIC ERROR VARIANCE=     900.0

N       AFTK     AFTK(INDEP)   DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1      0.002      0.002          0.0               0.0
 2      0.004      0.004          0.0               0.0
 3      0.005      0.006          0.0               0.0
 4      0.007      0.008          0.001             0.075
 5      0.009      0.009          0.001             0.100
 6      0.010      0.011          0.001             0.125
 7      0.011      0.013          0.002             0.151
 8      0.013      0.015          0.002             0.176
 9      0.014      0.017          0.003             0.201
10      0.015      0.019          0.003             0.226
11      0.016      0.021          0.004             0.252
12      0.018      0.022          0.005             0.277
13      0.019      0.024          0.006             0.302
14      0.020      0.026          0.006             0.328
15      0.021      0.028          0.007             0.353
```

```
LETHAL RADIUS=   10.0
TARGET DENSITY VARIANCE=   12100.0
TARGET LOCATION ERROR VARIANCE=   40000.0
BALLISTIC ERROR VARIANCE=    3600.0

N       AFTK     AFTK(INDEP)   DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1      0.002      0.002          0.0               0.0
 2      0.004      0.004          0.0               0.0
 3      0.005      0.005          0.0               0.0
 4      0.007      0.007          0.0               0.0
 5      0.009      0.009          0.0               0.0
 6      0.010      0.011          0.0               0.0
 7      0.012      0.012          0.0               0.0
 8      0.014      0.014          0.001             0.043
 9      0.015      0.016          0.001             0.049
10      0.017      0.018          0.001             0.055
11      0.018      0.020          0.001             0.061
12      0.020      0.021          0.001             0.067
13      0.021      0.023          0.002             0.074
14      0.023      0.025          0.002             0.080
15      0.024      0.027          0.002             0.086
```

```
LETHAL RADIUS=    10.0
TARGET DENSITY VARIANCE=    12100.0
TARGET LOCATION ERROR VARIANCE=   160000.0
BALLISTIC ERROR VARIANCE=       0.0

N         AFTK      AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1        0.001       0.001           0.0                0.0
 2        0.001       0.001           0.0                0.0
 3        0.001       0.002           0.001              0.636
 4        0.001       0.002           0.001              0.919
 5        0.001       0.003           0.002              1.188
 6        0.001       0.003           0.002              1.446
 7        0.002       0.004           0.003              1.696
 8        0.002       0.005           0.003              1.939
 9        0.002       0.005           0.004              2.175
10        0.002       0.006           0.004              2.407
11        0.002       0.006           0.005              2.634
12        0.002       0.007           0.005              2.856
13        0.002       0.008           0.006              3.076
14        0.002       0.008           0.006              3.292
15        0.002       0.009           0.007              3.505
```

```
LETHAL RADIUS=    10.0
TARGET DENSITY VARIANCE=    12100.0
TARGET LOCATION ERROR VARIANCE=   160000.0
BALLISTIC ERROR VARIANCE=      900.0

N         AFTK      AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1        0.001       0.001           0.0                0.0
 2        0.001       0.001           0.0                0.0
 3        0.002       0.002           0.0                0.0
 4        0.002       0.002           0.0                0.0
 5        0.003       0.003           0.0                0.0
 6        0.003       0.003           0.0                0.0
 7        0.003       0.004           0.001              0.154
 8        0.004       0.005           0.001              0.180
 9        0.004       0.005           0.001              0.206
10        0.005       0.006           0.001              0.232
11        0.005       0.006           0.001              0.258
12        0.005       0.007           0.002              0.284
13        0.006       0.007           0.002              0.310
14        0.006       0.008           0.002              0.336
15        0.006       0.009           0.002              0.362
```

```
LETHAL RADIUS=    10.0
TARGET DENSITY VARIANCE=    12100.0
TARGET LOCATION ERROR VARIANCE=   160000.0
BALLISTIC ERROR VARIANCE=     3600.0

N         AFTK      AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1        0.001       0.001           0.0                0.0
 2        0.001       0.001           0.0                0.0
 3        0.002       0.002           0.0                0.0
 4        0.002       0.002           0.0                0.0
 5        0.003       0.003           0.0                0.0
 6        0.003       0.003           0.0                0.0
 7        0.004       0.004           0.0                0.0
 8        0.004       0.005           0.0                0.0
 9        0.005       0.005           0.0                0.0
10        0.005       0.006           0.0                0.0
11        0.006       0.006           0.0                0.0
12        0.006       0.007           0.0                0.0
13        0.007       0.007           0.001              0.079
14        0.007       0.008           0.001              0.086
15        0.008       0.008           0.001              0.093
```

```
LETHAL RADIUS=   10.0
TARGET DENSITY VARIANCE=   44100.0
TARGET LOCATION ERROR VARIANCE=        0.0
BALLISTIC ERROR VARIANCE=        0.0

N        AFTK      AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1       0.002       0.002          0.0                 0.0
 2       0.003       0.005          0.001               0.332
 3       0.004       0.007          0.003               0.634
 4       0.005       0.009          0.004               0.915
 5       0.005       0.011          0.006               1.182
 6       0.006       0.013          0.008               1.438
 7       0.006       0.016          0.010               1.685
 8       0.006       0.018          0.012               1.925
 9       0.006       0.020          0.014               2.158
10       0.007       0.022          0.016               2.385
11       0.007       0.025          0.018               2.608
12       0.007       0.027          0.020               2.826
13       0.007       0.029          0.022               3.040
14       0.007       0.031          0.024               3.251
15       0.007       0.033          0.026               3.459
```

```
LETHAL RADIUS=   10.0
TARGET DENSITY VARIANCE=   44100.0
TARGET LOCATION ERROR VARIANCE=        0.0
BALLISTIC ERROR VARIANCE=      900.0

N        AFTK      AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1       0.002       0.002          0.0                 0.0
 2       0.004       0.004          0.0                 0.0
 3       0.006       0.007          0.0                 0.0
 4       0.008       0.009          0.001               0.075
 5       0.010       0.011          0.001               0.100
 6       0.012       0.013          0.001               0.125
 7       0.013       0.015          0.002               0.150
 8       0.015       0.018          0.003               0.175
 9       0.016       0.020          0.003               0.200
10       0.018       0.022          0.004               0.225
11       0.019       0.024          0.005               0.250
12       0.021       0.026          0.006               0.275
13       0.022       0.028          0.007               0.300
14       0.023       0.031          0.008               0.325
15       0.024       0.033          0.008               0.350
```

```
LETHAL RADIUS=   10.0
TARGET DENSITY VARIANCE=   44100.0
TARGET LOCATION ERROR VARIANCE=        0.0
BALLISTIC ERROR VARIANCE=     3600.0

N        AFTK      AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1       0.002       0.002          0.0                 0.0
 2       0.004       0.004          0.0                 0.0
 3       0.006       0.006          0.0                 0.0
 4       0.008       0.008          0.0                 0.0
 5       0.010       0.010          0.0                 0.0
 6       0.012       0.012          0.0                 0.0
 7       0.014       0.015          0.001               0.036
 8       0.016       0.017          0.001               0.042
 9       0.018       0.019          0.001               0.048
10       0.020       0.021          0.001               0.054
11       0.021       0.023          0.001               0.060
12       0.023       0.025          0.002               0.066
13       0.025       0.027          0.002               0.072
14       0.027       0.029          0.002               0.078
15       0.029       0.031          0.002               0.084
```

```
LETHAL RADIUS=   10.0
TARGET DENSITY VARIANCE=   44100.0
TARGET LOCATION ERROR VARIANCE=   40000.0
BALLISTIC ERROR VARIANCE=        0.0

N       AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1      0.001       0.001          0.0                0.0
 2      0.002       0.002          0.001              0.333
 3      0.002       0.004          0.001              0.635
 4      0.002       0.005          0.002              0.917
 5      0.003       0.006          0.003              1.186
 6      0.003       0.007          0.004              1.443
 7      0.003       0.008          0.005              1.692
 8      0.003       0.009          0.006              1.934
 9      0.003       0.011          0.007              2.169
10      0.003       0.012          0.008              2.399
11      0.004       0.013          0.009              2.624
12      0.004       0.014          0.010              2.845
13      0.004       0.015          0.012              3.063
14      0.004       0.016          0.013              3.277
15      0.004       0.018          0.014              3.488
```

```
LETHAL RADIUS=   10.0
TARGET DENSITY VARIANCE=   44100.0
TARGET LOCATION ERROR VARIANCE=   40000.0
BALLISTIC ERROR VARIANCE=      900.0

N       AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1      0.001       0.001          0.0                0.0
 2      0.002       0.002          0.0                0.0
 3      0.003       0.004          0.0                0.0
 4      0.004       0.005          0.0                0.0
 5      0.005       0.006          0.001              0.101
 6      0.006       0.007          0.001              0.127
 7      0.007       0.008          0.001              0.152
 8      0.008       0.009          0.001              0.178
 9      0.009       0.011          0.002              0.204
10      0.010       0.012          0.002              0.229
11      0.010       0.013          0.003              0.255
12      0.011       0.014          0.003              0.281
13      0.012       0.015          0.004              0.306
14      0.012       0.016          0.004              0.332
15      0.013       0.017          0.005              0.358
```

```
LETHAL RADIUS=   10.0
TARGET DENSITY VARIANCE=   44100.0
TARGET LOCATION ERROR VARIANCE=   40000.0
BALLISTIC ERROR VARIANCE=     3600.0

N       AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1      0.001       0.001          0.0                0.0
 2      0.002       0.002          0.0                0.0
 3      0.003       0.003          0.0                0.0
 4      0.004       0.005          0.0                0.0
 5      0.006       0.006          0.0                0.0
 6      0.007       0.007          0.0                0.0
 7      0.008       0.008          0.0                0.0
 8      0.009       0.009          0.0                0.0
 9      0.010       0.010          0.0                0.0
10      0.011       0.011          0.001              0.058
11      0.012       0.012          0.001              0.064
12      0.013       0.014          0.001              0.070
13      0.014       0.015          0.001              0.077
14      0.015       0.016          0.001              0.083
15      0.016       0.017          0.001              0.090
```

```
LETHAL RADIUS=   10.0
TARGET DENSITY VARIANCE=   44100.0
TARGET LOCATION ERROR VARIANCE=  160000.0
BALLISTIC ERROR VARIANCE=        0.0

N        AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1       0.000       0.000          0.0                0.0
 2       0.001       0.001          0.0                0.0
 3       0.001       0.001          0.001              0.636
 4       0.001       0.002          0.001              0.919
 5       0.001       0.002          0.001              1.188
 6       0.001       0.003          0.002              1.447
 7       0.001       0.003          0.002              1.697
 8       0.001       0.004          0.003              1.939
 9       0.001       0.004          0.003              2.176
10       0.001       0.005          0.003              2.408
11       0.001       0.005          0.004              2.635
12       0.002       0.006          0.004              2.858
13       0.002       0.006          0.005              3.078
14       0.002       0.007          0.005              3.294
15       0.002       0.007          0.006              3.507
```

```
LETHAL RADIUS=   10.0
TARGET DENSITY VARIANCE=   44100.0
TARGET LOCATION ERROR VARIANCE=  160000.0
BALLISTIC ERROR VARIANCE=      900.0

N        AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1       0.000       0.000          0.0                0.0
 2       0.001       0.001          0.0                0.0
 3       0.001       0.001          0.0                0.0
 4       0.002       0.002          0.0                0.0
 5       0.002       0.002          0.0                0.0
 6       0.003       0.003          0.0                0.0
 7       0.003       0.003          0.0                0.0
 8       0.003       0.004          0.001              0.180
 9       0.004       0.004          0.001              0.206
10       0.004       0.005          0.001              0.232
11       0.004       0.005          0.001              0.258
12       0.005       0.006          0.001              0.284
13       0.005       0.006          0.001              0.311
14       0.005       0.007          0.002              0.337
15       0.005       0.007          0.002              0.363
```

```
LETHAL RADIUS=   10.0
TARGET DENSITY VARIANCE=   44100.0
TARGET LOCATION ERROR VARIANCE=  160000.0
BALLISTIC ERROR VARIANCE=     3600.0

N        AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1       0.000       0.000          0.0                0.0
 2       0.001       0.001          0.0                0.0
 3       0.001       0.001          0.0                0.0
 4       0.002       0.002          0.0                0.0
 5       0.002       0.002          0.0                0.0
 6       0.003       0.003          0.0                0.0
 7       0.003       0.003          0.0                0.0
 8       0.004       0.004          0.0                0.0
 9       0.004       0.004          0.0                0.0
10       0.005       0.005          0.0                0.0
11       0.005       0.005          0.0                0.0
12       0.005       0.006          0.0                0.0
13       0.006       0.006          0.0                0.0
14       0.006       0.007          0.001              0.087
15       0.007       0.007          0.001              0.093
```

```
LETHAL RADIUS=    30.0
TARGET DENSITY VARIANCE=       100.0
TARGET LOCATION ERROR VARIANCE=         0.0
BALLISTIC ERROR VARIANCE=         0.0

N        AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1       0.900       0.900            0.0                0.0
 2       0.982       0.990            0.008              0.008
 3       0.995       0.999            0.004              0.004
 4       0.999       1.000            0.001              0.001
 5       1.000       1.000            0.0                0.0
 6       1.000       1.000            0.0                0.0
 7       1.000       1.000            0.0                0.0
 8       1.000       1.000            0.0                0.0
 9       1.000       1.000            0.0                0.0
10       1.000       1.000            0.0                0.0
11       1.000       1.000            0.0                0.0
12       1.000       1.000            0.0                0.0
13       1.000       1.000            0.0                0.0
14       1.000       1.000            0.0                0.0
15       1.000       1.000            0.0                0.0


LETHAL RADIUS=    30.0
TARGET DENSITY VARIANCE=       100.0
TARGET LOCATION ERROR VARIANCE=         0.0
BALLISTIC ERROR VARIANCE=      900.0

N        AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1       0.474       0.474            0.0                0.0
 2       0.722       0.723            0.001              0.001
 3       0.853       0.854            0.001              0.001
 4       0.922       0.923            0.001              0.001
 5       0.959       0.960            0.001              0.001
 6       0.978       0.979            0.001              0.001
 7       0.988       0.989            0.001              0.001
 8       0.994       0.994            0.0                0.0
 9       0.997       0.997            0.0                0.0
10       0.998       0.998            0.0                0.0
11       0.999       0.999            0.0                0.0
12       0.999       1.000            0.0                0.0
13       1.000       1.000            0.0                0.0
14       1.000       1.000            0.0                0.0
15       1.000       1.000            0.0                0.0


LETHAL RADIUS=    30.0
TARGET DENSITY VARIANCE=       100.0
TARGET LOCATION ERROR VARIANCE=         0.0
BALLISTIC ERROR VARIANCE=     3600.0

N        AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1       0.196       0.196            0.0                0.0
 2       0.353       0.353            0.0                0.0
 3       0.480       0.480            0.0                0.0
 4       0.581       0.581            0.0                0.0
 5       0.663       0.663            0.0                0.0
 6       0.729       0.729            0.0                0.0
 7       0.782       0.782            0.0                0.0
 8       0.825       0.825            0.0                0.0
 9       0.859       0.859            0.0                0.0
10       0.886       0.887            0.0                0.0
11       0.909       0.909            0.0                0.0
12       0.927       0.927            0.0                0.0
13       0.941       0.941            0.0                0.0
14       0.952       0.953            0.0                0.0
15       0.962       0.962            0.0                0.0
```

```
LETHAL RADIUS=   30.0
TARGET DENSITY VARIANCE=      100.0
TARGET LOCATION ERROR VARIANCE=   40000.0
BALLISTIC ERROR VARIANCE=       0.0

N        AFTK     AFTK(INDEP)   DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1       0.022      0.022          0.0               0.0
 2       0.033      0.043          0.011             0.324
 3       0.040      0.064          0.024             0.611
 4       0.045      0.085          0.040             0.874
 5       0.050      0.105          0.055             1.117
 6       0.053      0.125          0.072             1.346
 7       0.056      0.144          0.088             1.562
 8       0.059      0.163          0.104             1.766
 9       0.061      0.181          0.120             1.961
10       0.063      0.199          0.136             2.146
11       0.065      0.217          0.151             2.324
12       0.067      0.234          0.167             2.494
13       0.069      0.251          0.182             2.658
14       0.070      0.267          0.197             2.815
15       0.071      0.283          0.212             2.966


LETHAL RADIUS=   30.0
TARGET DENSITY VARIANCE=      100.0
TARGET LOCATION ERROR VARIANCE=   40000.0
BALLISTIC ERROR VARIANCE=     900.0

N        AFTK     AFTK(INDEP)   DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1       0.021      0.021          0.0               0.0
 2       0.037      0.042          0.005             0.134
 3       0.050      0.063          0.013             0.266
 4       0.060      0.083          0.024             0.394
 5       0.068      0.103          0.035             0.518
 6       0.075      0.122          0.048             0.638
 7       0.080      0.141          0.061             0.754
 8       0.086      0.159          0.074             0.865
 9       0.090      0.178          0.087             0.971
10       0.094      0.195          0.101             1.074
11       0.098      0.212          0.115             1.173
12       0.101      0.229          0.128             1.268
13       0.104      0.246          0.142             1.359
14       0.107      0.262          0.155             1.447
15       0.110      0.278          0.168             1.532


LETHAL RADIUS=   30.0
TARGET DENSITY VARIANCE=      100.0
TARGET LOCATION ERROR VARIANCE=   40000.0
BALLISTIC ERROR VARIANCE=    3600.0

N        AFTK     AFTK(INDEP)   DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1       0.020      0.020          0.0               0.0
 2       0.038      0.040          0.002             0.045
 3       0.054      0.059          0.005             0.090
 4       0.069      0.078          0.009             0.134
 5       0.082      0.097          0.015             0.177
 6       0.094      0.115          0.021             0.220
 7       0.105      0.133          0.028             0.263
 8       0.115      0.150          0.035             0.304
 9       0.125      0.168          0.043             0.345
10       0.133      0.184          0.051             0.385
11       0.141      0.201          0.060             0.424
12       0.148      0.217          0.069             0.463
13       0.155      0.233          0.078             0.500
14       0.162      0.248          0.087             0.537
15       0.168      0.263          0.096             0.573
```

```
LETHAL RADIUS=   30.0
TARGET DENSITY VARIANCE=       100.0
TARGET LOCATION ERROR VARIANCE=  160000.0
BALLISTIC ERROR VARIANCE=        0.0

N       AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1      0.006      0.006           0.0                 0.0
 2      0.008      0.011           0.003               0.331
 3      0.010      0.017           0.006               0.630
 4      0.012      0.022           0.011               0.908
 5      0.013      0.028           0.015               1.171
 6      0.014      0.033           0.019               1.422
 7      0.014      0.038           0.024               1.664
 8      0.015      0.044           0.029               1.897
 9      0.016      0.049           0.033               2.123
10      0.016      0.055           0.038               2.343
11      0.017      0.060           0.043               2.558
12      0.017      0.065           0.048               2.767
13      0.018      0.070           0.053               2.972
14      0.018      0.075           0.057               3.173
15      0.018      0.081           0.062               3.370


LETHAL RADIUS=   30.0
TARGET DENSITY VARIANCE=       100.0
TARGET LOCATION ERROR VARIANCE=  160000.0
BALLISTIC ERROR VARIANCE=      900.0

N       AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1      0.006      0.006           0.0                 0.0
 2      0.010      0.011           0.001               0.141
 3      0.013      0.017           0.004               0.281
 4      0.016      0.022           0.007               0.419
 5      0.018      0.027           0.010               0.555
 6      0.019      0.033           0.013               0.688
 7      0.021      0.038           0.017               0.818
 8      0.022      0.044           0.021               0.946
 9      0.024      0.049           0.025               1.070
10      0.025      0.054           0.029               1.192
11      0.026      0.059           0.034               1.312
12      0.027      0.065           0.038               1.429
13      0.027      0.070           0.042               1.544
14      0.028      0.075           0.047               1.657
15      0.029      0.080           0.051               1.767


LETHAL RADIUS=   30.0
TARGET DENSITY VARIANCE=       100.0
TARGET LOCATION ERROR VARIANCE=  160000.0
BALLISTIC ERROR VARIANCE=     3600.0

N       AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1      0.005      0.005           0.0                 0.0
 2      0.010      0.011           0.001               0.051
 3      0.015      0.016           0.001               0.101
 4      0.019      0.022           0.003               0.152
 5      0.022      0.027           0.005               0.203
 6      0.026      0.032           0.007               0.253
 7      0.029      0.038           0.009               0.304
 8      0.032      0.043           0.011               0.354
 9      0.034      0.048           0.014               0.404
10      0.037      0.053           0.017               0.454
11      0.039      0.059           0.020               0.503
12      0.041      0.064           0.023               0.553
13      0.043      0.069           0.026               0.601
14      0.045      0.074           0.029               0.650
15      0.047      0.079           0.032               0.697
```

```
LETHAL RADIUS=   30.0
TARGET DENSITY VARIANCE=   12100.0
TARGET LOCATION ERROR VARIANCE=        0.0
BALLISTIC ERROR VARIANCE=        0.0

N      AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1     0.069      0.069           0.0               0.0
 2     0.103      0.134           0.031             0.303
 3     0.124      0.194           0.069             0.558
 4     0.140      0.249           0.109             0.778
 5     0.153      0.301           0.149             0.971
 6     0.163      0.350           0.187             1.142
 7     0.172      0.395           0.223             1.294
 8     0.180      0.437           0.257             1.430
 9     0.186      0.476           0.289             1.552
10     0.192      0.512           0.320             1.661
11     0.198      0.546           0.348             1.759
12     0.203      0.577           0.374             1.846
13     0.207      0.606           0.399             1.925
14     0.212      0.634           0.422             1.996
15     0.215      0.659           0.444             2.060


LETHAL RADIUS=   30.0
TARGET DENSITY VARIANCE=   12100.0
TARGET LOCATION ERROR VARIANCE=        0.0
BALLISTIC ERROR VARIANCE=      900.0

N      AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1     0.065      0.065           0.0               0.0
 2     0.112      0.125           0.013             0.117
 3     0.148      0.182           0.034             0.227
 4     0.177      0.235           0.058             0.331
 5     0.199      0.284           0.085             0.426
 6     0.218      0.331           0.112             0.514
 7     0.235      0.374           0.140             0.595
 8     0.248      0.415           0.166             0.669
 9     0.261      0.453           0.192             0.736
10     0.271      0.488           0.217             0.798
11     0.281      0.521           0.240             0.854
12     0.290      0.552           0.262             0.904
13     0.298      0.581           0.283             0.950
14     0.305      0.608           0.303             0.992
15     0.312      0.634           0.321             1.030


LETHAL RADIUS=   30.0
TARGET DENSITY VARIANCE=   12100.0
TARGET LOCATION ERROR VARIANCE=        0.0
BALLISTIC ERROR VARIANCE=     3600.0

N      AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1     0.054      0.054           0.0               0.0
 2     0.102      0.105           0.003             0.033
 3     0.145      0.154           0.009             0.064
 4     0.183      0.200           0.017             0.094
 5     0.217      0.243           0.027             0.123
 6     0.247      0.284           0.037             0.151
 7     0.274      0.323           0.049             0.178
 8     0.299      0.360           0.061             0.203
 9     0.322      0.394           0.073             0.226
10     0.342      0.427           0.085             0.249
11     0.361      0.458           0.098             0.270
12     0.378      0.488           0.110             0.290
13     0.394      0.516           0.122             0.309
14     0.408      0.542           0.133             0.327
15     0.422      0.567           0.145             0.343
```

```
LETHAL RADIUS=   30.0
TARGET DENSITY VARIANCE=    12100.0
TARGET LOCATION ERROR VARIANCE=    40000.0
BALLISTIC ERROR VARIANCE=         0.0

N        AFTK      AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1       0.017        0.017           0.0                0.0
 2       0.025        0.034           0.008              0.326
 3       0.031        0.050           0.019              0.617
 4       0.035        0.066           0.031              0.884
 5       0.038        0.082           0.044              1.134
 6       0.041        0.098           0.056              1.369
 7       0.044        0.113           0.069              1.592
 8       0.046        0.128           0.082              1.805
 9       0.047        0.143           0.095              2.009
10       0.049        0.157           0.108              2.205
11       0.051        0.172           0.121              2.393
12       0.052        0.186           0.134              2.574
13       0.053        0.200           0.146              2.750
14       0.054        0.213           0.159              2.919
15       0.055        0.227           0.171              3.083


LETHAL RADIUS=   30.0
TARGET DENSITY VARIANCE=    12100.0
TARGET LOCATION ERROR VARIANCE=    40000.0
BALLISTIC ERROR VARIANCE=       900.0

N        AFTK      AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1       0.017        0.017           0.0                0.0
 2       0.029        0.033           0.004              0.136
 3       0.039        0.049           0.010              0.270
 4       0.046        0.065           0.019              0.401
 5       0.053        0.081           0.028              0.529
 6       0.058        0.096           0.038              0.653
 7       0.063        0.111           0.048              0.773
 8       0.067        0.126           0.059              0.888
 9       0.070        0.141           0.070              1.000
10       0.073        0.155           0.081              1.109
11       0.076        0.169           0.093              1.213
12       0.079        0.183           0.104              1.314
13       0.081        0.197           0.115              1.413
14       0.084        0.210           0.126              1.508
15       0.086        0.223           0.137              1.600


LETHAL RADIUS=   30.0
TARGET DENSITY VARIANCE=    12100.0
TARGET LOCATION ERROR VARIANCE=    40000.0
BALLISTIC ERROR VARIANCE=      3600.0

N        AFTK      AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1       0.016        0.016           0.0                0.0
 2       0.030        0.032           0.001              0.047
 3       0.043        0.047           0.004              0.093
 4       0.055        0.062           0.008              0.139
 5       0.065        0.077           0.012              0.184
 6       0.075        0.092           0.017              0.230
 7       0.083        0.106           0.023              0.274
 8       0.091        0.120           0.029              0.318
 9       0.099        0.134           0.036              0.362
10       0.105        0.148           0.043              0.404
11       0.112        0.162           0.050              0.446
12       0.118        0.175           0.057              0.488
13       0.123        0.188           0.065              0.528
14       0.128        0.201           0.073              0.568
15       0.133        0.214           0.081              0.607
```

```
LETHAL RADIUS=   30.0
TARGET DENSITY VARIANCE=   12100.0
TARGET LOCATION ERROR VARIANCE=  160000.0
BALLISTIC ERROR VARIANCE=       0.0

N      AFTK     AFTK(INDEP)   DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1     0.005      0.005          0.0               0.0
 2     0.008      0.010          0.003             0.331
 3     0.010      0.016          0.006             0.630
 4     0.011      0.021          0.010             0.909
 5     0.012      0.026          0.014             1.172
 6     0.013      0.031          0.018             1.424
 7     0.013      0.036          0.022             1.666
 8     0.014      0.041          0.027             1.900
 9     0.015      0.046          0.031             2.127
10     0.015      0.051          0.036             2.348
11     0.016      0.056          0.040             2.563
12     0.016      0.061          0.045             2.774
13     0.016      0.066          0.049             2.980
14     0.017      0.070          0.054             3.182
15     0.017      0.075          0.058             3.380
```

```
LETHAL RADIUS=   30.0
TARGET DENSITY VARIANCE=   12100.0
TARGET LOCATION ERROR VARIANCE=  160000.0
BALLISTIC ERROR VARIANCE=     900.0

N      AFTK     AFTK(INDEP)   DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1     0.005      0.005          0.0               0.0
 2     0.009      0.010          0.001             0.141
 3     0.012      0.015          0.003             0.281
 4     0.014      0.021          0.006             0.419
 5     0.016      0.026          0.009             0.556
 6     0.018      0.031          0.013             0.689
 7     0.020      0.036          0.016             0.820
 8     0.021      0.041          0.020             0.948
 9     0.022      0.046          0.024             1.073
10     0.023      0.051          0.028             1.195
11     0.024      0.055          0.032             1.316
12     0.025      0.060          0.036             1.433
13     0.026      0.065          0.040             1.549
14     0.026      0.070          0.044             1.662
15     0.027      0.075          0.048             1.773
```

```
LETHAL RADIUS=   30.0
TARGET DENSITY VARIANCE=   12100.0
TARGET LOCATION ERROR VARIANCE=  160000.0
BALLISTIC ERROR VARIANCE=    3600.0

N      AFTK     AFTK(INDEP)   DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1     0.005      0.005          0.0               0.0
 2     0.010      0.010          0.0               0.0
 3     0.014      0.015          0.001             0.102
 4     0.018      0.020          0.003             0.152
 5     0.021      0.025          0.004             0.203
 6     0.024      0.030          0.006             0.254
 7     0.027      0.035          0.008             0.305
 8     0.030      0.040          0.011             0.356
 9     0.032      0.045          0.013             0.406
10     0.034      0.050          0.016             0.456
11     0.036      0.055          0.018             0.506
12     0.038      0.059          0.021             0.555
13     0.040      0.064          0.024             0.604
14     0.042      0.069          0.027             0.653
15     0.043      0.074          0.030             0.701
```

```
LETHAL RADIUS=    30.0
TARGET DENSITY VARIANCE=    44100.0
TARGET LOCATION ERROR VARIANCE=         0.0
BALLISTIC ERROR VARIANCE=          0.0

N       AFTK      AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1      0.020        0.020          0.0                0.0
 2      0.030        0.040          0.010              0.324
 3      0.036        0.059          0.022              0.613
 4      0.041        0.078          0.036              0.878
 5      0.045        0.096          0.051              1.124
 6      0.048        0.114          0.066              1.355
 7      0.051        0.132          0.081              1.573
 8      0.054        0.149          0.096              1.781
 9      0.056        0.166          0.110              1.979
10      0.058        0.183          0.125              2.169
11      0.059        0.199          0.140              2.351
12      0.061        0.215          0.154              2.526
13      0.063        0.231          0.168              2.694
14      0.064        0.246          0.182              2.855
15      0.065        0.261          0.196              3.011
```

```
LETHAL RADIUS=    30.0
TARGET DENSITY VARIANCE=    44100.0
TARGET LOCATION ERROR VARIANCE=         0.0
BALLISTIC ERROR VARIANCE=        900.0

N       AFTK      AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1      0.020        0.020          0.0                0.0
 2      0.034        0.039          0.005              0.135
 3      0.046        0.058          0.012              0.268
 4      0.055        0.076          0.022              0.397
 5      0.062        0.094          0.032              0.523
 6      0.068        0.112          0.044              0.644
 7      0.074        0.129          0.056              0.761
 8      0.078        0.147          0.068              0.874
 9      0.082        0.163          0.081              0.983
10      0.086        0.180          0.094              1.087
11      0.089        0.196          0.106              1.188
12      0.093        0.212          0.119              1.286
13      0.095        0.227          0.132              1.380
14      0.098        0.242          0.144              1.471
15      0.100        0.257          0.157              1.558
```

```
LETHAL RADIUS=    30.0
TARGET DENSITY VARIANCE=    44100.0
TARGET LOCATION ERROR VARIANCE=         0.0
BALLISTIC ERROR VARIANCE=       3600.0

N       AFTK      AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1      0.019        0.019          0.0                0.0
 2      0.035        0.037          0.002              0.046
 3      0.050        0.055          0.005              0.091
 4      0.063        0.072          0.009              0.136
 5      0.076        0.089          0.014              0.180
 6      0.087        0.106          0.019              0.224
 7      0.097        0.123          0.026              0.267
 8      0.106        0.139          0.033              0.310
 9      0.115        0.155          0.040              0.351
10      0.122        0.170          0.048              0.392
11      0.130        0.186          0.056              0.433
12      0.136        0.201          0.064              0.472
13      0.143        0.216          0.073              0.511
14      0.149        0.230          0.082              0.549
15      0.154        0.245          0.090              0.586
```

```
LETHAL RADIUS=   30.0
TARGET DENSITY VARIANCE=   44100.0
TARGET LOCATION ERROR VARIANCE=   40000.0
BALLISTIC ERROR VARIANCE=        0.0

N       AFTK      AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1      0.011       0.011           0.0                0.0
 2      0.016       0.021           0.005              0.329
 3      0.019       0.031           0.012              0.624
 4      0.022       0.042           0.020              0.897
 5      0.024       0.052           0.028              1.154
 6      0.026       0.062           0.036              1.399
 7      0.027       0.072           0.045              1.632
 8      0.029       0.082           0.053              1.856
 9      0.030       0.091           0.062              2.072
10      0.031       0.101           0.070              2.281
11      0.032       0.110           0.079              2.484
12      0.033       0.120           0.087              2.681
13      0.033       0.129           0.096              2.872
14      0.034       0.138           0.104              3.059
15      0.035       0.148           0.113              3.241
```

```
LETHAL RADIUS=   30.0
TARGET DENSITY VARIANCE=   44100.0
TARGET LOCATION ERROR VARIANCE=   40000.0
BALLISTIC ERROR VARIANCE=      900.0

N       AFTK      AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1      0.010       0.010           0.0                0.0
 2      0.018       0.021           0.003              0.139
 3      0.024       0.031           0.007              0.276
 4      0.029       0.041           0.012              0.411
 5      0.033       0.051           0.018              0.543
 6      0.037       0.061           0.025              0.672
 7      0.040       0.071           0.032              0.798
 8      0.042       0.081           0.039              0.920
 9      0.044       0.090           0.046              1.039
10      0.046       0.100           0.054              1.155
11      0.048       0.109           0.061              1.268
12      0.050       0.119           0.069              1.378
13      0.051       0.128           0.076              1.485
14      0.053       0.137           0.084              1.589
15      0.054       0.146           0.092              1.691
```

```
LETHAL RADIUS=   30.0
TARGET DENSITY VARIANCE=   44100.0
TARGET LOCATION ERROR VARIANCE=   40000.0
BALLISTIC ERROR VARIANCE=     3600.0

N       AFTK      AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1      0.010       0.010           0.0                0.0
 2      0.019       0.020           0.001              0.049
 3      0.027       0.030           0.003              0.097
 4      0.035       0.040           0.005              0.146
 5      0.042       0.050           0.008              0.194
 6      0.048       0.059           0.012              0.243
 7      0.053       0.069           0.016              0.290
 8      0.059       0.078           0.020              0.338
 9      0.063       0.088           0.024              0.385
10      0.068       0.097           0.029              0.431
11      0.072       0.106           0.034              0.477
12      0.076       0.115           0.040              0.523
13      0.079       0.124           0.045              0.568
14      0.083       0.133           0.051              0.612
15      0.086       0.142           0.056              0.656
```

```
LETHAL RADIUS=   30.0
TARGET DENSITY VARIANCE=   44100.0
TARGET LOCATION ERROR VARIANCE=  160000.0
BALLISTIC ERROR VARIANCE=         0.0

N        AFTK     AFTK(INDEP)   DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1       0.004       0.004          0.0              0.0
 2       0.007       0.009          0.002            0.331
 3       0.008       0.013          0.005            0.631
 4       0.009       0.017          0.008            0.911
 5       0.010       0.022          0.012            1.175
 6       0.011       0.026          0.015            1.428
 7       0.011       0.030          0.019            1.671
 8       0.012       0.035          0.023            1.907
 9       0.012       0.039          0.026            2.136
10       0.013       0.043          0.030            2.358
11       0.013       0.047          0.034            2.576
12       0.014       0.051          0.038            2.788
13       0.014       0.056          0.042            2.997
14       0.014       0.060          0.046            3.201
15       0.015       0.064          0.049            3.402


LETHAL RADIUS=   30.0
TARGET DENSITY VARIANCE=   44100.0
TARGET LOCATION ERROR VARIANCE=  160000.0
BALLISTIC ERROR VARIANCE=       900.0

N        AFTK     AFTK(INDEP)   DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1       0.004       0.004          0.0              0.0
 2       0.008       0.009          0.001            0.141
 3       0.010       0.013          0.003            0.282
 4       0.012       0.017          0.005            0.421
 5       0.014       0.022          0.008            0.557
 6       0.015       0.026          0.011            0.692
 7       0.017       0.030          0.014            0.823
 8       0.018       0.034          0.017            0.952
 9       0.019       0.039          0.020            1.078
10       0.019       0.043          0.023            1.202
11       0.020       0.047          0.027            1.323
12       0.021       0.051          0.030            1.442
13       0.022       0.055          0.034            1.559
14       0.022       0.059          0.037            1.673
15       0.023       0.064          0.041            1.786


LETHAL RADIUS=   30.0
TARGET DENSITY VARIANCE=   44100.0
TARGET LOCATION ERROR VARIANCE=  160000.0
BALLISTIC ERROR VARIANCE=      3600.0

N        AFTK     AFTK(INDEP)   DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1       0.004       0.004          0.0              0.0
 2       0.008       0.009          0.0              0.0
 3       0.012       0.013          0.001            0.102
 4       0.015       0.017          0.002            0.153
 5       0.018       0.021          0.004            0.205
 6       0.020       0.026          0.005            0.256
 7       0.023       0.030          0.007            0.307
 8       0.025       0.034          0.009            0.358
 9       0.027       0.038          0.011            0.409
10       0.029       0.042          0.013            0.460
11       0.031       0.046          0.016            0.510
12       0.032       0.051          0.018            0.560
13       0.034       0.055          0.021            0.610
14       0.035       0.059          0.023            0.659
15       0.037       0.063          0.026            0.708
```

```
LETHAL RADIUS=   50.0
TARGET DENSITY VARIANCE=      100.0
TARGET LOCATION ERROR VARIANCE=         0.0
BALLISTIC ERROR VARIANCE=        0.0

N       AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1      0.962       0.962           0.0                 0.0
 2      0.997       0.999           0.001               0.001
 3      1.000       1.000           0.0                 0.0
 4      1.000       1.000           0.0                 0.0
 5      1.000       1.000           0.0                 0.0
 6      1.000       1.000           0.0                 0.0
 7      1.000       1.000           0.0                 0.0
 8      1.000       1.000           0.0                 0.0
 9      1.000       1.000           0.0                 0.0
10      1.000       1.000           0.0                 0.0
11      1.000       1.000           0.0                 0.0
12      1.000       1.000           0.0                 0.0
13      1.000       1.000           0.0                 0.0
14      1.000       1.000           0.0                 0.0
15      1.000       1.000           0.0                 0.0
```

```
LETHAL RADIUS=   50.0
TARGET DENSITY VARIANCE=      100.0
TARGET LOCATION ERROR VARIANCE=         0.0
BALLISTIC ERROR VARIANCE=      900.0

N       AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1      0.714       0.714           0.0                 0.0
 2      0.918       0.918           0.0                 0.0
 3      0.976       0.977           0.0                 0.0
 4      0.993       0.993           0.0                 0.0
 5      0.998       0.998           0.0                 0.0
 6      0.999       0.999           0.0                 0.0
 7      1.000       1.000           0.0                 0.0
 8      1.000       1.000           0.0                 0.0
 9      1.000       1.000           0.0                 0.0
10      1.000       1.000           0.0                 0.0
11      1.000       1.000           0.0                 0.0
12      1.000       1.000           0.0                 0.0
13      1.000       1.000           0.0                 0.0
14      1.000       1.000           0.0                 0.0
15      1.000       1.000           0.0                 0.0
```

```
LETHAL RADIUS=   50.0
TARGET DENSITY VARIANCE=      100.0
TARGET LOCATION ERROR VARIANCE=         0.0
BALLISTIC ERROR VARIANCE=     3600.0

N       AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1      0.403       0.403           0.0                 0.0
 2      0.644       0.644           0.0                 0.0
 3      0.787       0.787           0.0                 0.0
 4      0.873       0.873           0.0                 0.0
 5      0.924       0.924           0.0                 0.0
 6      0.955       0.955           0.0                 0.0
 7      0.973       0.973           0.0                 0.0
 8      0.984       0.984           0.0                 0.0
 9      0.990       0.990           0.0                 0.0
10      0.994       0.994           0.0                 0.0
11      0.997       0.997           0.0                 0.0
12      0.998       0.998           0.0                 0.0
13      0.999       0.999           0.0                 0.0
14      0.999       0.999           0.0                 0.0
15      1.000       1.000           0.0                 0.0
```

```
LETHAL RADIUS=   50.0
TARGET DENSITY VARIANCE=       100.0
TARGET LOCATION ERROR VARIANCE=    40000.0
BALLISTIC ERROR VARIANCE=         0.0

N       AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1      0.059      0.059           0.0               0.0
 2      0.087      0.114           0.027             0.307
 3      0.106      0.166           0.060             0.569
 4      0.119      0.215           0.095             0.799
 5      0.130      0.261           0.131             1.003
 6      0.139      0.304           0.165             1.186
 7      0.147      0.345           0.198             1.351
 8      0.153      0.384           0.230             1.500
 9      0.159      0.420           0.260             1.636
10      0.164      0.454           0.289             1.759
11      0.169      0.486           0.317             1.872
12      0.173      0.516           0.343             1.975
13      0.177      0.544           0.367             2.069
14      0.181      0.571           0.390             2.155
15      0.184      0.596           0.412             2.233


LETHAL RADIUS=   50.0
TARGET DENSITY VARIANCE=       100.0
TARGET LOCATION ERROR VARIANCE=    40000.0
BALLISTIC ERROR VARIANCE=       900.0

N       AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1      0.057      0.057           0.0               0.0
 2      0.093      0.112           0.019             0.201
 3      0.117      0.163           0.045             0.386
 4      0.136      0.211           0.075             0.555
 5      0.150      0.256           0.106             0.708
 6      0.162      0.299           0.137             0.847
 7      0.172      0.339           0.167             0.974
 8      0.181      0.377           0.197             1.089
 9      0.188      0.413           0.225             1.195
10      0.195      0.447           0.252             1.291
11      0.201      0.479           0.277             1.379
12      0.207      0.508           0.302             1.459
13      0.212      0.537           0.325             1.533
14      0.217      0.563           0.347             1.600
15      0.221      0.588           0.367             1.662


LETHAL RADIUS=   50.0
TARGET DENSITY VARIANCE=       100.0
TARGET LOCATION ERROR VARIANCE=    40000.0
BALLISTIC ERROR VARIANCE=     3600.0

N       AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1      0.054      0.054           0.0               0.0
 2      0.096      0.105           0.009             0.093
 3      0.130      0.154           0.024             0.182
 4      0.157      0.200           0.042             0.267
 5      0.180      0.243           0.063             0.347
 6      0.199      0.284           0.084             0.423
 7      0.216      0.323           0.107             0.494
 8      0.230      0.359           0.129             0.560
 9      0.243      0.394           0.151             0.621
10      0.254      0.427           0.172             0.678
11      0.264      0.458           0.193             0.731
12      0.274      0.487           0.214             0.781
13      0.282      0.515           0.233             0.826
14      0.290      0.541           0.251             0.868
15      0.297      0.566           0.269             0.907
```

```
LETHAL RADIUS=   50.0
TARGET DENSITY VARIANCE=       100.0
TARGET LOCATION ERROR VARIANCE=   160000.0
BALLISTIC ERROR VARIANCE=         0.0

N       AFTK     AFTK(INDEP)   DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1      0.015       0.015          0.0                0.0
 2      0.023       0.031          0.008              0.327
 3      0.028       0.045          0.017              0.619
 4      0.032       0.060          0.028              0.887
 5      0.035       0.075          0.040              1.139
 6      0.037       0.089          0.051              1.376
 7      0.040       0.103          0.063              1.602
 8      0.041       0.117          0.075              1.818
 9      0.043       0.130          0.087              2.025
10      0.045       0.144          0.099              2.224
11      0.046       0.157          0.111              2.415
12      0.047       0.170          0.123              2.601
13      0.048       0.182          0.134              2.780
14      0.049       0.195          0.146              2.954
15      0.050       0.207          0.157              3.122
```

```
LETHAL RADIUS=   50.0
TARGET DENSITY VARIANCE=       100.0
TARGET LOCATION ERROR VARIANCE=   160000.0
BALLISTIC ERROR VARIANCE=       900.0

N       AFTK     AFTK(INDEP)   DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1      0.015       0.015          0.0                0.0
 2      0.025       0.030          0.005              0.219
 3      0.032       0.045          0.014              0.428
 4      0.037       0.060          0.023              0.628
 5      0.041       0.074          0.033              0.818
 6      0.044       0.088          0.044              1.000
 7      0.047       0.102          0.055              1.173
 8      0.050       0.116          0.066              1.339
 9      0.052       0.129          0.078              1.499
10      0.054       0.143          0.089              1.653
11      0.056       0.156          0.100              1.802
12      0.057       0.169          0.112              1.945
13      0.059       0.182          0.123              2.084
14      0.060       0.194          0.134              2.219
15      0.062       0.206          0.145              2.350
```

```
LETHAL RADIUS=   50.0
TARGET DENSITY VARIANCE=       100.0
TARGET LOCATION ERROR VARIANCE=   160000.0
BALLISTIC ERROR VARIANCE=      3600.0

N       AFTK     AFTK(INDEP)   DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1      0.015       0.015          0.0                0.0
 2      0.027       0.030          0.003              0.108
 3      0.037       0.044          0.008              0.216
 4      0.045       0.059          0.014              0.321
 5      0.051       0.073          0.022              0.425
 6      0.057       0.087          0.030              0.527
 7      0.062       0.101          0.039              0.626
 8      0.066       0.114          0.048              0.723
 9      0.070       0.128          0.057              0.817
10      0.074       0.141          0.067              0.909
11      0.077       0.154          0.077              0.998
12      0.080       0.166          0.087              1.084
13      0.082       0.179          0.096              1.169
14      0.085       0.191          0.106              1.250
15      0.087       0.203          0.116              1.330
```

```
LETHAL RADIUS=   50.0
TARGET DENSITY VARIANCE=   12100.0
TARGET LOCATION ERROR VARIANCE=        0.0
BALLISTIC ERROR VARIANCE=        0.0

N        AFTK      AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1       0.171       0.171           0.0                0.0
 2       0.249       0.313           0.064              0.258
 3       0.297       0.431           0.134              0.449
 4       0.332       0.528           0.196              0.592
 5       0.358       0.609           0.251              0.700
 6       0.380       0.676           0.296              0.781
 7       0.397       0.731           0.334              0.841
 8       0.413       0.777           0.365              0.884
 9       0.426       0.816           0.390              0.915
10       0.437       0.847           0.410              0.937
11       0.448       0.873           0.426              0.950
12       0.457       0.895           0.438              0.958
13       0.466       0.913           0.447              0.961
14       0.473       0.928           0.455              0.960
15       0.481       0.940           0.460              0.957
```

```
LETHAL RADIUS=   50.0
TARGET DENSITY VARIANCE=   12100.0
TARGET LOCATION ERROR VARIANCE=        0.0
BALLISTIC ERROR VARIANCE=      900.0

N        AFTK      AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1       0.161       0.161           0.0                0.0
 2       0.256       0.297           0.041              0.159
 3       0.318       0.410           0.092              0.289
 4       0.363       0.505           0.143              0.393
 5       0.396       0.585           0.189              0.476
 6       0.423       0.652           0.229              0.540
 7       0.446       0.708           0.262              0.589
 8       0.464       0.755           0.291              0.626
 9       0.481       0.795           0.314              0.653
10       0.495       0.828           0.333              0.673
11       0.507       0.856           0.348              0.686
12       0.519       0.879           0.360              0.694
13       0.529       0.898           0.370              0.699
14       0.538       0.915           0.377              0.700
15       0.547       0.929           0.382              0.699
```

```
LETHAL RADIUS=   50.0
TARGET DENSITY VARIANCE=   12100.0
TARGET LOCATION ERROR VARIANCE=        0.0
BALLISTIC ERROR VARIANCE=     3600.0

N        AFTK      AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1       0.137       0.137           0.0                0.0
 2       0.241       0.256           0.015              0.062
 3       0.321       0.358           0.038              0.117
 4       0.383       0.446           0.063              0.165
 5       0.433       0.522           0.089              0.206
 6       0.474       0.588           0.114              0.241
 7       0.507       0.645           0.137              0.270
 8       0.536       0.693           0.158              0.294
 9       0.560       0.735           0.176              0.314
10       0.581       0.772           0.191              0.329
11       0.599       0.803           0.204              0.341
12       0.615       0.830           0.215              0.350
13       0.629       0.854           0.224              0.356
14       0.642       0.874           0.231              0.360
15       0.654       0.891           0.237              0.363
```

```
LETHAL RADIUS=   50.0
TARGET DENSITY VARIANCE=   12100.0
TARGET LOCATION ERROR VARIANCE=   40000.0
BALLISTIC ERROR VARIANCE=        0.0

N      AFTK     AFTK(INDEP)   DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1     0.046       0.046          0.0               0.0
 2     0.068       0.089          0.021             0.313
 3     0.083       0.131          0.048             0.584
 4     0.094       0.171          0.077             0.825
 5     0.102       0.209          0.107             1.042
 6     0.109       0.245          0.136             1.240
 7     0.115       0.280          0.164             1.422
 8     0.121       0.313          0.192             1.589
 9     0.125       0.344          0.219             1.744
10     0.130       0.374          0.245             1.887
11     0.133       0.403          0.269             2.020
12     0.137       0.430          0.293             2.144
13     0.140       0.456          0.316             2.259
14     0.143       0.481          0.338             2.366
15     0.146       0.505          0.359             2.466
```

```
LETHAL RADIUS=   50.0
TARGET DENSITY VARIANCE=   12100.0
TARGET LOCATION ERROR VARIANCE=   40000.0
BALLISTIC ERROR VARIANCE=      900.0

N      AFTK     AFTK(INDEP)   DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1     0.045       0.045          0.0               0.0
 2     0.073       0.088          0.015             0.206
 3     0.092       0.129          0.037             0.398
 4     0.107       0.168          0.062             0.576
 5     0.118       0.206          0.087             0.739
 6     0.128       0.242          0.114             0.890
 7     0.136       0.276          0.140             1.030
 8     0.143       0.308          0.166             1.159
 9     0.149       0.340          0.191             1.278
10     0.155       0.369          0.215             1.390
11     0.160       0.398          0.238             1.493
12     0.164       0.425          0.261             1.589
13     0.168       0.451          0.282             1.679
14     0.172       0.475          0.303             1.763
15     0.176       0.499          0.323             1.841
```

```
LETHAL RADIUS=   50.0
TARGET DENSITY VARIANCE=   12100.0
TARGET LOCATION ERROR VARIANCE=   40000.0
BALLISTIC ERROR VARIANCE=     3600.0

N      AFTK     AFTK(INDEP)   DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1     0.043       0.043          0.0               0.0
 2     0.077       0.084          0.007             0.097
 3     0.104       0.123          0.020             0.191
 4     0.126       0.161          0.035             0.282
 5     0.144       0.197          0.053             0.369
 6     0.160       0.232          0.072             0.451
 7     0.173       0.265          0.092             0.530
 8     0.185       0.296          0.111             0.604
 9     0.195       0.326          0.131             0.673
10     0.204       0.355          0.151             0.739
11     0.213       0.383          0.170             0.801
12     0.220       0.410          0.189             0.859
13     0.227       0.435          0.208             0.914
14     0.234       0.459          0.226             0.966
15     0.240       0.482          0.243             1.014
```

```
LETHAL RADIUS=   50.0
TARGET DENSITY VARIANCE=   12100.0
TARGET LOCATION ERROR VARIANCE=  160000.0
BALLISTIC ERROR VARIANCE=          0.0

N        AFTK      AFTK(INDEP)    DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1       0.014        0.014          0.0              0.0
 2       0.021        0.028          0.007            0.327
 3       0.026        0.042          0.016            0.620
 4       0.030        0.056          0.026            0.890
 5       0.032        0.070          0.037            1.142
 6       0.035        0.083          0.048            1.381
 7       0.037        0.096          0.059            1.609
 8       0.039        0.109          0.070            1.826
 9       0.040        0.122          0.082            2.035
10       0.041        0.134          0.093            2.236
11       0.043        0.147          0.104            2.430
12       0.044        0.159          0.115            2.618
13       0.045        0.171          0.126            2.800
14       0.046        0.183          0.137            2.976
15       0.047        0.195          0.148            3.148


LETHAL RADIUS=   50.0
TARGET DENSITY VARIANCE=   12100.0
TARGET LOCATION ERROR VARIANCE=  160000.0
BALLISTIC ERROR VARIANCE=       900.0

N        AFTK      AFTK(INDEP)    DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1       0.014        0.014          0.0              0.0
 2       0.023        0.028          0.005            0.219
 3       0.029        0.042          0.013            0.430
 4       0.034        0.056          0.022            0.630
 5       0.038        0.069          0.031            0.821
 6       0.041        0.082          0.041            1.004
 7       0.044        0.096          0.052            1.178
 8       0.046        0.108          0.062            1.346
 9       0.048        0.121          0.073            1.507
10       0.050        0.134          0.083            1.663
11       0.052        0.146          0.094            1.814
12       0.053        0.158          0.105            1.959
13       0.055        0.170          0.115            2.100
14       0.056        0.182          0.126            2.237
15       0.057        0.194          0.136            2.370


LETHAL RADIUS=   50.0
TARGET DENSITY VARIANCE=   12100.0
TARGET LOCATION ERROR VARIANCE=  160000.0
BALLISTIC ERROR VARIANCE=      3600.0

N        AFTK      AFTK(INDEP)    DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1       0.014        0.014          0.0              0.0
 2       0.025        0.028          0.003            0.109
 3       0.034        0.041          0.007            0.216
 4       0.042        0.055          0.013            0.323
 5       0.048        0.068          0.020            0.428
 6       0.053        0.081          0.028            0.530
 7       0.058        0.094          0.036            0.630
 8       0.062        0.107          0.045            0.728
 9       0.066        0.119          0.054            0.823
10       0.069        0.132          0.063            0.915
11       0.072        0.144          0.072            1.006
12       0.074        0.156          0.081            1.093
13       0.077        0.168          0.091            1.179
14       0.079        0.179          0.100            1.262
15       0.082        0.191          0.109            1.343
```

```
LETHAL RADIUS=    50.0
TARGET DENSITY VARIANCE=    44100.0
TARGET LOCATION ERROR VARIANCE=          0.0
BALLISTIC ERROR VARIANCE=          0.0

N          AFTK      AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1         0.054       0.054             0.0                0.0
 2         0.080       0.104             0.025              0.310
 3         0.097       0.152             0.056              0.575
 4         0.109       0.198             0.089              0.809
 5         0.119       0.241             0.122              1.018
 6         0.128       0.282             0.154              1.207
 7         0.135       0.320             0.186              1.378
 8         0.141       0.357             0.216              1.534
 9         0.146       0.391             0.245              1.677
10         0.151       0.424             0.273              1.808
11         0.155       0.455             0.299              1.929
12         0.159       0.484             0.325              2.039
13         0.163       0.512             0.349              2.141
14         0.166       0.538             0.372              2.235
15         0.169       0.563             0.393              2.321


LETHAL RADIUS=    50.0
TARGET DENSITY VARIANCE=    44100.0
TARGET LOCATION ERROR VARIANCE=          0.0
BALLISTIC ERROR VARIANCE=        900.0

N          AFTK      AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1         0.053       0.053             0.0                0.0
 2         0.085       0.102             0.017              0.203
 3         0.108       0.150             0.042              0.391
 4         0.124       0.194             0.070              0.563
 5         0.138       0.237             0.099              0.720
 6         0.149       0.277             0.128              0.864
 7         0.158       0.315             0.157              0.995
 8         0.166       0.351             0.185              1.116
 9         0.173       0.385             0.212              1.227
10         0.179       0.418             0.238              1.328
11         0.185       0.448             0.263              1.422
12         0.190       0.477             0.287              1.509
13         0.195       0.505             0.310              1.588
14         0.199       0.531             0.331              1.662
15         0.204       0.556             0.352              1.729


LETHAL RADIUS=    50.0
TARGET DENSITY VARIANCE=    44100.0
TARGET LOCATION ERROR VARIANCE=          0.0
BALLISTIC ERROR VARIANCE=       3600.0

N          AFTK      AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1         0.050       0.050             0.0                0.0
 2         0.089       0.097             0.008              0.094
 3         0.120       0.142             0.022              0.186
 4         0.145       0.185             0.040              0.273
 5         0.166       0.225             0.059              0.356
 6         0.184       0.264             0.080              0.434
 7         0.199       0.301             0.101              0.507
 8         0.213       0.335             0.123              0.576
 9         0.225       0.369             0.144              0.641
10         0.235       0.400             0.165              0.701
11         0.245       0.430             0.185              0.758
12         0.253       0.458             0.205              0.810
13         0.261       0.485             0.224              0.859
14         0.268       0.511             0.243              0.905
15         0.275       0.535             0.260              0.947
```

```
LETHAL RADIUS=    50.0
TARGET DENSITY VARIANCE=    44100.0
TARGET LOCATION ERROR VARIANCE=    40000.0
BALLISTIC ERROR VARIANCE=       0.0

N        AFTK      AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1       0.029        0.029          0.0                0.0
 2       0.043        0.057          0.014              0.321
 3       0.052        0.084          0.032              0.603
 4       0.059        0.111          0.051              0.859
 5       0.065        0.136          0.071              1.095
 6       0.070        0.161          0.092              1.315
 7       0.074        0.185          0.112              1.520
 8       0.077        0.209          0.132              1.713
 9       0.080        0.232          0.152              1.895
10       0.083        0.254          0.171              2.068
11       0.085        0.275          0.190              2.232
12       0.087        0.296          0.209              2.387
13       0.090        0.317          0.227              2.535
14       0.092        0.336          0.245              2.676
15       0.093        0.356          0.262              2.811


LETHAL RADIUS=    50.0
TARGET DENSITY VARIANCE=    44100.0
TARGET LOCATION ERROR VARIANCE=    40000.0
BALLISTIC ERROR VARIANCE=     900.0

N        AFTK      AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1       0.029        0.029          0.0                0.0
 2       0.046        0.056          0.010              0.213
 3       0.059        0.083          0.024              0.415
 4       0.068        0.109          0.041              0.605
 5       0.076        0.135          0.059              0.782
 6       0.082        0.160          0.078              0.950
 7       0.087        0.184          0.097              1.107
 8       0.092        0.207          0.115              1.256
 9       0.096        0.230          0.134              1.397
10       0.099        0.252          0.152              1.531
11       0.103        0.273          0.170              1.657
12       0.106        0.294          0.188              1.778
13       0.109        0.314          0.205              1.893
14       0.111        0.334          0.222              2.003
15       0.113        0.353          0.239              2.107


LETHAL RADIUS=    50.0
TARGET DENSITY VARIANCE=    44100.0
TARGET LOCATION ERROR VARIANCE=    40000.0
BALLISTIC ERROR VARIANCE=    3600.0

N        AFTK      AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1       0.028        0.028          0.0                0.0
 2       0.050        0.055          0.005              0.103
 3       0.067        0.081          0.014              0.204
 4       0.082        0.106          0.025              0.303
 5       0.094        0.131          0.037              0.399
 6       0.104        0.155          0.051              0.492
 7       0.113        0.179          0.066              0.581
 8       0.121        0.201          0.081              0.667
 9       0.128        0.224          0.096              0.750
10       0.134        0.245          0.111              0.829
11       0.140        0.266          0.126              0.904
12       0.145        0.286          0.141              0.977
13       0.150        0.306          0.157              1.047
14       0.154        0.325          0.171              1.113
15       0.158        0.344          0.186              1.177
```

```
LETHAL RADIUS=    50.0
TARGET DENSITY VARIANCE=    44100.0
TARGET LOCATION ERROR VARIANCE=   160000.0
BALLISTIC ERROR VARIANCE=        0.0

N        AFTK      AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1       0.012       0.012          0.0                0.0
 2       0.018       0.024          0.006              0.328
 3       0.022       0.036          0.014              0.622
 4       0.025       0.048          0.022              0.894
 5       0.027       0.059          0.032              1.149
 6       0.029       0.070          0.041              1.391
 7       0.031       0.082          0.051              1.622
 8       0.033       0.093          0.060              1.844
 9       0.034       0.104          0.070              2.057
10       0.035       0.115          0.079              2.263
11       0.036       0.125          0.089              2.462
12       0.037       0.136          0.099              2.655
13       0.038       0.146          0.108              2.843
14       0.039       0.157          0.118              3.025
15       0.040       0.167          0.127              3.203
```

```
LETHAL RADIUS=    50.0
TARGET DENSITY VARIANCE=    44100.0
TARGET LOCATION ERROR VARIANCE=   160000.0
BALLISTIC ERROR VARIANCE=      900.0

N        AFTK      AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1       0.012       0.012          0.0                0.0
 2       0.020       0.024          0.004              0.220
 3       0.025       0.036          0.011              0.432
 4       0.029       0.047          0.018              0.634
 5       0.032       0.059          0.027              0.827
 6       0.035       0.070          0.035              1.012
 7       0.037       0.081          0.044              1.189
 8       0.039       0.092          0.053              1.360
 9       0.041       0.103          0.062              1.525
10       0.043       0.114          0.072              1.684
11       0.044       0.125          0.081              1.839
12       0.045       0.135          0.090              1.988
13       0.047       0.146          0.099              2.134
14       0.048       0.156          0.108              2.275
15       0.049       0.166          0.118              2.413
```

```
LETHAL RADIUS=    50.0
TARGET DENSITY VARIANCE=    44100.0
TARGET LOCATION ERROR VARIANCE=   160000.0
BALLISTIC ERROR VARIANCE=     3600.0

N        AFTK      AFTK(INDEP)    DIFF(ABSOLUTE)     DIFF(RELATIVE)

 1       0.012       0.012          0.0                0.0
 2       0.021       0.024          0.002              0.109
 3       0.029       0.035          0.006              0.218
 4       0.035       0.047          0.011              0.326
 5       0.041       0.058          0.018              0.432
 6       0.045       0.069          0.024              0.536
 7       0.049       0.080          0.031              0.638
 8       0.053       0.091          0.039              0.738
 9       0.056       0.102          0.046              0.835
10       0.058       0.113          0.054              0.930
11       0.061       0.123          0.062              1.022
12       0.063       0.134          0.070              1.113
13       0.065       0.144          0.079              1.201
14       0.067       0.154          0.087              1.287
15       0.069       0.164          0.095              1.371
```

APPENDIX B

COMPUTER OUTPUT FOR SPECIFIC WEAPONS

These tables contain values for N, the number of rounds fired in the salvo, AFTK, the average fraction of target killed for the dependent model, AFTK(INDEP), the average fraction of target killed for the independent model, DIFF(ABSOLUTE), the absolute difference, and DIFF(RELATIVE), the relative difference.

Ballistic input data was for the following weapons and ranges.

WEAPON	RANGES (meters)		
105mm howitzer	2500	5000	10,000
155mm howitzer	5000	10,000	15,000
8 inch howitzer	5000	10,000	14,500
175mm gun	10,000	20,000	30,000

See APPENDIX E for the computer program.

```
LETHAL RADIUS-RANGE=    15.0
LETHAL RADIUS-DEFLECTION=    15.0

MEAN TARGET LOCATION ERROR-RANGE= -158.1
MEAN TARGET LOCATION ERROR-DEFLECTION=    32.0

TARGET DENSITY STANDARD DEVIATION-RANGE=     8.3
TARGET DENSITY STANDARD DEVIATION-DEFLECTION=     8.3

BALLISTIC ERROR STANDARD DEVIATION-RANGE=    11.9
BALLISTIC ERROR STANDARD DEVIATION-DEFLECTION=     1.5

TARGET LOCATION ERROR STANDARD DEVIATION-RANGE=   163.1
TARGET LOCATION ERROR STANDARD DEVIATION-DEFLECTION=    94.9

N       AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1      0.008       0.008            0.0                0.0
 2      0.014       0.017            0.003              0.239
 3      0.017       0.025            0.008              0.468
 4      0.020       0.033            0.014              0.685
 5      0.022       0.042            0.020              0.893
 6      0.024       0.050            0.026              1.093
 7      0.025       0.058            0.032              1.285
 8      0.027       0.066            0.039              1.470
 9      0.028       0.074            0.046              1.649
10      0.029       0.081            0.053              1.823
11      0.030       0.089            0.059              1.993
12      0.031       0.097            0.066              2.157
13      0.032       0.105            0.073              2.318
14      0.032       0.112            0.080              2.475
15      0.033       0.120            0.087              2.629
```

```
LETHAL RADIUS-RANGE=    15.0
LETHAL RADIUS-DEFLECTION=    15.0

MEAN TARGET LOCATION ERROR-RANGE= -158.1
MEAN TARGET LOCATION ERROR-DEFLECTION=    32.0

TARGET DENSITY STANDARD DEVIATION-RANGE=     8.3
TARGET DENSITY STANDARD DEVIATION-DEFLECTION=     8.3

BALLISTIC ERROR STANDARD DEVIATION-RANGE=    11.9
BALLISTIC ERROR STANDARD DEVIATION-DEFLECTION=     1.5

TARGET LOCATION ERROR STANDARD DEVIATION-RANGE=   778.3
TARGET LOCATION ERROR STANDARD DEVIATION-DEFLECTION=    94.9

N       AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1      0.003       0.003            0.0                0.0
 2      0.004       0.006            0.001              0.242
 3      0.006       0.008            0.003              0.476
 4      0.007       0.011            0.005              0.700
 5      0.007       0.014            0.007              0.915
 6      0.008       0.017            0.009              1.122
 7      0.008       0.019            0.011              1.324
 8      0.009       0.022            0.013              1.519
 9      0.009       0.025            0.016              1.710
10      0.009       0.027            0.018              1.896
11      0.010       0.030            0.020              2.078
12      0.010       0.033            0.023              2.256
13      0.010       0.036            0.025              2.432
14      0.011       0.038            0.028              2.604
15      0.011       0.041            0.030              2.774
```

```
LETHAL RADIUS-RANGE=    15.0
LETHAL RADIUS-DEFLECTION=    15.0

MEAN TARGET LOCATION ERROR-RANGE= -158.1
MEAN TARGET LOCATION ERROR-DEFLECTION=    32.0

TARGET DENSITY STANDARD DEVIATION-RANGE=     8.3
TARGET DENSITY STANDARD DEVIATION-DEFLECTION=     8.3

BALLISTIC ERROR STANDARD DEVIATION-RANGE=    11.9
BALLISTIC ERROR STANDARD DEVIATION-DEFLECTION=     1.5

TARGET LOCATION ERROR STANDARD DEVIATION-RANGE= 1366.9
TARGET LOCATION ERROR STANDARD DEVIATION-DEFLECTION=    94.9

N        AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1       0.002       0.002            0.0               0.0
 2       0.003       0.003            0.001             0.243
 3       0.003       0.005            0.002             0.477
 4       0.004       0.006            0.003             0.703
 5       0.004       0.008            0.004             0.919
 6       0.005       0.010            0.005             1.129
 7       0.005       0.011            0.006             1.332
 8       0.005       0.013            0.008             1.529
 9       0.005       0.014            0.009             1.722
10       0.005       0.016            0.010             1.911
11       0.006       0.018            0.012             2.095
12       0.006       0.019            0.013             2.277
13       0.006       0.021            0.015             2.455
14       0.006       0.022            0.016             2.631
15       0.006       0.024            0.018             2.804
```

```
LETHAL RADIUS-RANGE=    15.0
LETHAL RADIUS-DEFLECTION=    15.0

MEAN TARGET LOCATION ERROR-RANGE= -158.1
MEAN TARGET LOCATION ERROR-DEFLECTION=    32.0

TARGET DENSITY STANDARD DEVIATION-RANGE=     8.3
TARGET DENSITY STANDARD DEVIATION-DEFLECTION=     8.3

BALLISTIC ERROR STANDARD DEVIATION-RANGE=    16.3
BALLISTIC ERROR STANDARD DEVIATION-DEFLECTION=     4.4

TARGET LOCATION ERROR STANDARD DEVIATION-RANGE=  163.1
TARGET LOCATION ERROR STANDARD DEVIATION-DEFLECTION=    94.9

N        AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1       0.008       0.008            0.0               0.0
 2       0.014       0.017            0.003             0.190
 3       0.018       0.025            0.007             0.376
 4       0.021       0.033            0.012             0.556
 5       0.024       0.042            0.018             0.730
 6       0.026       0.050            0.023             0.898
 7       0.028       0.058            0.030             1.061
 8       0.030       0.066            0.036             1.219
 9       0.031       0.074            0.043             1.372
10       0.032       0.081            0.049             1.520
11       0.033       0.089            0.056             1.665
12       0.034       0.097            0.062             1.806
13       0.035       0.104            0.069             1.944
14       0.036       0.112            0.076             2.078
15       0.037       0.119            0.082             2.209
```

```
LETHAL RADIUS-RANGE=   15.0
LETHAL RADIUS-DEFLECTION=   15.0

MEAN TARGET LOCATION ERROR-RANGE= -158.1
MEAN TARGET LOCATION ERROR-DEFLECTION=   32.0

TARGET DENSITY STANDARD DEVIATION-RANGE=    8.3
TARGET DENSITY STANDARD DEVIATION-DEFLECTION=    8.3

BALLISTIC ERROR STANDARD DEVIATION-RANGE=   16.3
BALLISTIC ERROR STANDARD DEVIATION-DEFLECTION=    4.4

TARGET LOCATION ERROR STANDARD DEVIATION-RANGE=  778.3
TARGET LOCATION ERROR STANDARD DEVIATION-DEFLECTION=   94.9

N       AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1      0.003      0.003           0.0               0.0
 2      0.005      0.006           0.001             0.193
 3      0.006      0.008           0.002             0.384
 4      0.007      0.011           0.004             0.569
 5      0.008      0.014           0.006             0.750
 6      0.009      0.017           0.008             0.925
 7      0.009      0.019           0.010             1.096
 8      0.010      0.022           0.012             1.263
 9      0.010      0.025           0.015             1.426
10      0.011      0.027           0.017             1.585
11      0.011      0.030           0.019             1.741
12      0.011      0.033           0.021             1.894
13      0.012      0.035           0.024             2.044
14      0.012      0.038           0.026             2.192
15      0.012      0.041           0.029             2.337
```

```
LETHAL RADIUS-RANGE=   15.0
LETHAL RADIUS-DEFLECTION=   15.0

MEAN TARGET LOCATION ERROR-RANGE= -158.1
MEAN TARGET LOCATION ERROR-DEFLECTION=   32.0

TARGET DENSITY STANDARD DEVIATION-RANGE=    8.3
TARGET DENSITY STANDARD DEVIATION-DEFLECTION=    8.3

BALLISTIC ERROR STANDARD DEVIATION-RANGE=   16.3
BALLISTIC ERROR STANDARD DEVIATION-DEFLECTION=    4.4

TARGET LOCATION ERROR STANDARD DEVIATION-RANGE= 1366.9
TARGET LOCATION ERROR STANDARD DEVIATION-DEFLECTION=   94.9

N       AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1      0.002      0.002           0.0               0.0
 2      0.003      0.003           0.001             0.194
 3      0.003      0.005           0.001             0.385
 4      0.004      0.006           0.002             0.572
 5      0.005      0.008           0.003             0.754
 6      0.005      0.010           0.005             0.931
 7      0.005      0.011           0.006             1.103
 8      0.006      0.013           0.007             1.272
 9      0.006      0.014           0.008             1.437
10      0.006      0.016           0.010             1.598
11      0.006      0.017           0.011             1.756
12      0.007      0.019           0.013             1.912
13      0.007      0.021           0.014             2.065
14      0.007      0.022           0.015             2.216
15      0.007      0.024           0.017             2.364
```

```
LETHAL RADIUS-RANGE=   15.0
LETHAL RADIUS-DEFLECTION=   15.0

MEAN TARGET LOCATION ERROR-RANGE= -158.1
MEAN TARGET LOCATION ERROR-DEFLECTION=   32.0

TARGET DENSITY STANDARD DEVIATION-RANGE=    8.3
TARGET DENSITY STANDARD DEVIATION-DEFLECTION=    8.3

BALLISTIC ERROR STANDARD DEVIATION-RANGE=   28.2
BALLISTIC ERROR STANDARD DEVIATION-DEFLECTION=   10.4

TARGET LOCATION ERROR STANDARD DEVIATION-RANGE=  163.1
TARGET LOCATION ERROR STANDARD DEVIATION-DEFLECTION=   94.9

N       AFTK      AFTK(INDEP)    DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1      0.008       0.008           0.0               0.0
 2      0.015       0.017           0.002             0.103
 3      0.021       0.025           0.004             0.207
 4      0.025       0.033           0.008             0.309
 5      0.029       0.041           0.012             0.411
 6      0.033       0.049           0.017             0.510
 7      0.036       0.057           0.022             0.609
 8      0.038       0.065           0.027             0.705
 9      0.041       0.073           0.033             0.800
10      0.043       0.081           0.038             0.893
11      0.045       0.089           0.044             0.984
12      0.046       0.096           0.050             1.073
13      0.048       0.104           0.056             1.161
14      0.050       0.111           0.062             1.247
15      0.051       0.119           0.068             1.331
```

```
LETHAL RADIUS-RANGE=   15.0
LETHAL RADIUS-DEFLECTION=   15.0

MEAN TARGET LOCATION ERROR-RANGE= -158.1
MEAN TARGET LOCATION ERROR-DEFLECTION=   32.0

TARGET DENSITY STANDARD DEVIATION-RANGE=    8.3
TARGET DENSITY STANDARD DEVIATION-DEFLECTION=    8.3

BALLISTIC ERROR STANDARD DEVIATION-RANGE=   28.2
BALLISTIC ERROR STANDARD DEVIATION-DEFLECTION=   10.4

TARGET LOCATION ERROR STANDARD DEVIATION-RANGE=  778.3
TARGET LOCATION ERROR STANDARD DEVIATION-DEFLECTION=   94.9

N       AFTK      AFTK(INDEP)    DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1      0.003       0.003           0.0               0.0
 2      0.005       0.006           0.001             0.106
 3      0.007       0.008           0.001             0.213
 4      0.008       0.011           0.003             0.320
 5      0.010       0.014           0.004             0.426
 6      0.011       0.016           0.006             0.532
 7      0.012       0.019           0.007             0.636
 8      0.013       0.022           0.009             0.739
 9      0.013       0.025           0.011             0.841
10      0.014       0.027           0.013             0.941
11      0.015       0.030           0.015             1.040
12      0.015       0.033           0.017             1.138
13      0.016       0.035           0.020             1.234
14      0.016       0.038           0.022             1.329
15      0.017       0.041           0.024             1.423
```

```
LETHAL RADIUS-RANGE=   15.0
LETHAL RADIUS-DEFLECTION=   15.0

MEAN TARGET LOCATION ERROR-RANGE= -158.1
MEAN TARGET LOCATION ERROR-DEFLECTION=   32.0

TARGET DENSITY STANDARD DEVIATION-RANGE=    8.3
TARGET DENSITY STANDARD DEVIATION-DEFLECTION=    8.3

BALLISTIC ERROR STANDARD DEVIATION-RANGE=   28.2
BALLISTIC ERROR STANDARD DEVIATION-DEFLECTION=   10.4

TARGET LOCATION ERROR STANDARD DEVIATION-RANGE= 1366.9
TARGET LOCATION ERROR STANDARD DEVIATION-DEFLECTION=   94.9

N      AFTK    AFTK(INDEP)   DIFF(ABSOLUTE)   DIFF(RELATIVE)

 1     0.002      0.002          0.0              0.0
 2     0.003      0.003          0.0              0.0
 3     0.004      0.005          0.001            0.215
 4     0.005      0.006          0.002            0.322
 5     0.006      0.008          0.002            0.429
 6     0.006      0.010          0.003            0.536
 7     0.007      0.011          0.004            0.641
 8     0.007      0.013          0.005            0.746
 9     0.008      0.014          0.007            0.849
10     0.008      0.016          0.008            0.951
11     0.008      0.017          0.009            1.051
12     0.009      0.019          0.010            1.151
13     0.009      0.021          0.011            1.249
14     0.009      0.022          0.013            1.346
15     0.010      0.024          0.014            1.442
```

```
LETHAL RADIUS-RANGE=    25.0
LETHAL RADIUS-DEFLECTION=    25.0

MEAN TARGET LOCATION ERROR-RANGE= -158.1
MEAN TARGET LOCATION ERROR-DEFLECTION=    32.0

TARGET DENSITY STANDARD DEVIATION-RANGE=     8.3
TARGET DENSITY STANDARD DEVIATION-DEFLECTION=     8.3

BALLISTIC ERROR STANDARD DEVIATION-RANGE=    16.3
BALLISTIC ERROR STANDARD DEVIATION-DEFLECTION=     3.0

TARGET LOCATION ERROR STANDARD DEVIATION-RANGE=   163.1
TARGET LOCATION ERROR STANDARD DEVIATION-DEFLECTION=    94.9

N        AFTK      AFTK(INDEP)    DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1       0.023       0.023           0.0                0.0
 2       0.036       0.046           0.009              0.253
 3       0.045       0.068           0.022              0.489
 4       0.052       0.089           0.037              0.709
 5       0.057       0.110           0.053              0.916
 6       0.062       0.130           0.069              1.110
 7       0.066       0.150           0.085              1.293
 8       0.069       0.170           0.101              1.467
 9       0.072       0.189           0.117              1.633
10       0.074       0.208           0.133              1.791
11       0.077       0.226           0.149              1.942
12       0.079       0.244           0.165              2.087
13       0.081       0.261           0.180              2.226
14       0.083       0.278           0.195              2.359
15       0.085       0.295           0.210              2.487
```

```
LETHAL RADIUS-RANGE=    25.0
LETHAL RADIUS-DEFLECTION=    25.0

MEAN TARGET LOCATION ERROR-RANGE= -158.1
MEAN TARGET LOCATION ERROR-DEFLECTION=    32.0

TARGET DENSITY STANDARD DEVIATION-RANGE=     8.3
TARGET DENSITY STANDARD DEVIATION-DEFLECTION=     8.3

BALLISTIC ERROR STANDARD DEVIATION-RANGE=    16.3
BALLISTIC ERROR STANDARD DEVIATION-DEFLECTION=     3.0

TARGET LOCATION ERROR STANDARD DEVIATION-RANGE=   778.3
TARGET LOCATION ERROR STANDARD DEVIATION-DEFLECTION=    94.9

N        AFTK      AFTK(INDEP)    DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1       0.008       0.008           0.0                0.0
 2       0.012       0.015           0.003              0.263
 3       0.015       0.023           0.008              0.512
 4       0.017       0.030           0.013              0.749
 5       0.019       0.037           0.018              0.975
 6       0.020       0.045           0.024              1.192
 7       0.022       0.052           0.030              1.401
 8       0.023       0.059           0.036              1.602
 9       0.024       0.066           0.042              1.798
10       0.024       0.073           0.049              1.988
11       0.025       0.080           0.055              2.173
12       0.026       0.087           0.061              2.354
13       0.027       0.094           0.067              2.530
14       0.027       0.101           0.074              2.703
15       0.028       0.108           0.080              2.872
```

```
LETHAL RADIUS-RANGE=   25.0
LETHAL RADIUS-DEFLECTION=   25.0

MEAN TARGET LOCATION ERROR-RANGE= -158.1
MEAN TARGET LOCATION ERROR-DEFLECTION=   32.0

TARGET DENSITY STANDARD DEVIATION-RANGE=    8.3
TARGET DENSITY STANDARD DEVIATION-DEFLECTION=    8.3

BALLISTIC ERROR STANDARD DEVIATION-RANGE=   16.3
BALLISTIC ERROR STANDARD DEVIATION-DEFLECTION=    3.0

TARGET LOCATION ERROR STANDARD DEVIATION-RANGE= 1366.9
TARGET LOCATION ERROR STANDARD DEVIATION-DEFLECTION=   94.9

N      AFTK     AFTK(INDEP)   DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1     0.004      0.004          0.0               0.0
 2     0.007      0.009          0.002             0.265
 3     0.009      0.013          0.004             0.517
 4     0.010      0.017          0.007             0.757
 5     0.011      0.022          0.011             0.988
 6     0.012      0.026          0.014             1.209
 7     0.012      0.030          0.018             1.423
 8     0.013      0.034          0.021             1.631
 9     0.014      0.039          0.025             1.833
10     0.014      0.043          0.029             2.030
11     0.015      0.047          0.032             2.223
12     0.015      0.051          0.036             2.412
13     0.015      0.055          0.040             2.597
14     0.016      0.059          0.044             2.778
15     0.016      0.064          0.048             2.957
```

```
LETHAL RADIUS-RANGE=   25.0
LETHAL RADIUS-DEFLECTION=   25.0

MEAN TARGET LOCATION ERROR-RANGE= -158.1
MEAN TARGET LOCATION ERROR-DEFLECTION=   32.0

TARGET DENSITY STANDARD DEVIATION-RANGE=    8.3
TARGET DENSITY STANDARD DEVIATION-DEFLECTION=    8.3

BALLISTIC ERROR STANDARD DEVIATION-RANGE=   40.0
BALLISTIC ERROR STANDARD DEVIATION-DEFLECTION=    5.9

TARGET LOCATION ERROR STANDARD DEVIATION-RANGE=  163.1
TARGET LOCATION ERROR STANDARD DEVIATION-DEFLECTION=   94.9

N      AFTK     AFTK(INDEP)   DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1     0.023      0.023          0.0               0.0
 2     0.040      0.045          0.005             0.138
 3     0.053      0.067          0.014             0.273
 4     0.063      0.089          0.025             0.403
 5     0.072      0.110          0.038             0.530
 6     0.079      0.130          0.051             0.651
 7     0.085      0.150          0.065             0.767
 8     0.090      0.169          0.079             0.879
 9     0.095      0.188          0.094             0.986
10     0.099      0.207          0.108             1.089
11     0.103      0.225          0.122             1.187
12     0.107      0.243          0.137             1.282
13     0.110      0.260          0.151             1.373
14     0.113      0.277          0.165             1.460
15     0.116      0.294          0.178             1.544
```

```
LETHAL RADIUS-RANGE=    25.0
LETHAL RADIUS-DEFLECTION=    25.0

MEAN TARGET LOCATION ERROR-RANGE= -158.1
MEAN TARGET LOCATION ERROR-DEFLECTION=    32.0

TARGET DENSITY STANDARD DEVIATION-RANGE=     8.3
TARGET DENSITY STANDARD DEVIATION-DEFLECTION=     8.3

BALLISTIC ERROR STANDARD DEVIATION-RANGE=   40.0
BALLISTIC ERROR STANDARD DEVIATION-DEFLECTION=     5.9

TARGET LOCATION ERROR STANDARD DEVIATION-RANGE=  778.3
TARGET LOCATION ERROR STANDARD DEVIATION-DEFLECTION=    94.9

N      AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1     0.008      0.008           0.0               0.0
 2     0.013      0.015           0.002             0.146
 3     0.017      0.022           0.005             0.292
 4     0.021      0.030           0.009             0.435
 5     0.024      0.037           0.014             0.576
 6     0.026      0.044           0.019             0.714
 7     0.028      0.052           0.024             0.848
 8     0.030      0.059           0.029             0.980
 9     0.031      0.066           0.035             1.108
10     0.033      0.073           0.040             1.233
11     0.034      0.080           0.046             1.355
12     0.035      0.087           0.052             1.475
13     0.036      0.094           0.058             1.592
14     0.037      0.101           0.063             1.707
15     0.038      0.107           0.069             1.820
```

```
LETHAL RADIUS-RANGE=    25.0
LETHAL RADIUS-DEFLECTION=    25.0

MEAN TARGET LOCATION ERROR-RANGE= -158.1
MEAN TARGET LOCATION ERROR-DEFLECTION=    32.0

TARGET DENSITY STANDARD DEVIATION-RANGE=     8.3
TARGET DENSITY STANDARD DEVIATION-DEFLECTION=     8.3

BALLISTIC ERROR STANDARD DEVIATION-RANGE=   40.0
BALLISTIC ERROR STANDARD DEVIATION-DEFLECTION=     5.9

TARGET LOCATION ERROR STANDARD DEVIATION-RANGE= 1366.9
TARGET LOCATION ERROR STANDARD DEVIATION-DEFLECTION=    94.9

N      AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1     0.004      0.004           0.0               0.0
 2     0.008      0.009           0.001             0.148
 3     0.010      0.013           0.003             0.296
 4     0.012      0.017           0.005             0.442
 5     0.014      0.022           0.008             0.586
 6     0.015      0.026           0.011             0.727
 7     0.016      0.030           0.014             0.865
 8     0.017      0.034           0.017             1.001
 9     0.018      0.039           0.021             1.134
10     0.019      0.043           0.024             1.264
11     0.020      0.047           0.027             1.392
12     0.020      0.051           0.031             1.517
13     0.021      0.055           0.034             1.640
14     0.022      0.059           0.038             1.761
15     0.022      0.064           0.041             1.880
```

```
LETHAL RADIUS-RANGE=   25.0
LETHAL RADIUS-DEFLECTION=   25.0

MEAN TARGET LOCATION ERROR-RANGE= -158.1
MEAN TARGET LOCATION ERROR-DEFLECTION=   32.0

TARGET DENSITY STANDARD DEVIATION-RANGE=    8.3
TARGET DENSITY STANDARD DEVIATION-DEFLECTION=    8.3

BALLISTIC ERROR STANDARD DEVIATION-RANGE=   59.3
BALLISTIC ERROR STANDARD DEVIATION-DEFLECTION=    5.9

TARGET LOCATION ERROR STANDARD DEVIATION-RANGE=  163.1
TARGET LOCATION ERROR STANDARD DEVIATION-DEFLECTION=   94.9

N       AFTK      AFTK(INDEP)   DIFF(ABSOLUTE)   DIFF(RELATIVE)

 1      0.023      0.023          0.0              0.0
 2      0.041      0.045          0.004            0.094
 3      0.056      0.067          0.011            0.187
 4      0.069      0.088          0.019            0.278
 5      0.080      0.109          0.029            0.367
 6      0.089      0.129          0.040            0.454
 7      0.097      0.149          0.052            0.537
 8      0.104      0.169          0.064            0.619
 9      0.111      0.188          0.077            0.697
10      0.116      0.206          0.090            0.773
11      0.121      0.224          0.103            0.846
12      0.126      0.242          0.116            0.916
13      0.131      0.259          0.129            0.984
14      0.135      0.276          0.141            1.050
15      0.139      0.293          0.154            1.113
```

```
LETHAL RADIUS-RANGE=   25.0
LETHAL RADIUS-DEFLECTION=   25.0

MEAN TARGET LOCATION ERROR-RANGE= -158.1
MEAN TARGET LOCATION ERROR-DEFLECTION=   32.0

TARGET DENSITY STANDARD DEVIATION-RANGE=    8.3
TARGET DENSITY STANDARD DEVIATION-DEFLECTION=    8.3

BALLISTIC ERROR STANDARD DEVIATION-RANGE=   59.3
BALLISTIC ERROR STANDARD DEVIATION-DEFLECTION=    5.9

TARGET LOCATION ERROR STANDARD DEVIATION-RANGE=  778.3
TARGET LOCATION ERROR STANDARD DEVIATION-DEFLECTION=   94.9

N       AFTK      AFTK(INDEP)   DIFF(ABSOLUTE)   DIFF(RELATIVE)

 1      0.008      0.008          0.0              0.0
 2      0.014      0.015          0.001            0.102
 3      0.019      0.022          0.004            0.204
 4      0.023      0.030          0.007            0.306
 5      0.026      0.037          0.011            0.407
 6      0.029      0.044          0.015            0.507
 7      0.032      0.052          0.019            0.605
 8      0.035      0.059          0.024            0.702
 9      0.037      0.066          0.029            0.798
10      0.039      0.073          0.034            0.891
11      0.040      0.080          0.040            0.983
12      0.042      0.087          0.045            1.073
13      0.043      0.094          0.050            1.162
14      0.045      0.101          0.056            1.249
15      0.046      0.107          0.061            1.334
```

```
LETHAL RADIUS-RANGE=    25.0
LETHAL RADIUS-DEFLECTION=    25.0

MEAN TARGET LOCATION ERROR-RANGE= -158.1
MEAN TARGET LOCATION ERROR-DEFLECTION=    32.0

TARGET DENSITY STANDARD DEVIATION-RANGE=     8.3
TARGET DENSITY STANDARD DEVIATION-DEFLECTION=     8.3

BALLISTIC ERROR STANDARD DEVIATION-RANGE=    59.3
BALLISTIC ERROR STANDARD DEVIATION-DEFLECTION=     5.9

TARGET LOCATION ERROR STANDARD DEVIATION-RANGE= 1366.9
TARGET LOCATION ERROR STANDARD DEVIATION-DEFLECTION=    94.9

N       AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1      0.004       0.004          0.0               0.0
 2      0.008       0.009          0.001             0.104
 3      0.011       0.013          0.002             0.208
 4      0.013       0.017          0.004             0.312
 5      0.015       0.022          0.006             0.416
 6      0.017       0.026          0.009             0.518
 7      0.019       0.030          0.012             0.620
 8      0.020       0.034          0.014             0.720
 9      0.021       0.039          0.017             0.819
10      0.022       0.043          0.020             0.917
11      0.023       0.047          0.024             1.013
12      0.024       0.051          0.027             1.108
13      0.025       0.055          0.030             1.201
14      0.026       0.059          0.033             1.293
15      0.027       0.063          0.037             1.384
```

```
LETHAL RADIUS-RANGE=    40.0
LETHAL RADIUS-DEFLECTION=    40.0

MEAN TARGET LOCATION ERROR-RANGE= -158.1
MEAN TARGET LOCATION ERROR-DEFLECTION=    32.0

TARGET DENSITY STANDARD DEVIATION-RANGE=     8.3
TARGET DENSITY STANDARD DEVIATION-DEFLECTION=     8.3

BALLISTIC ERROR STANDARD DEVIATION-RANGE=    19.3
BALLISTIC ERROR STANDARD DEVIATION-DEFLECTION=     4.4

TARGET LOCATION ERROR STANDARD DEVIATION-RANGE=   163.1
TARGET LOCATION ERROR STANDARD DEVIATION-DEFLECTION=    94.9

N       AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1      0.056      0.056          0.0               0.0
 2      0.086      0.109          0.023             0.266
 3      0.106      0.160          0.053             0.502
 4      0.121      0.207          0.086             0.713
 5      0.132      0.252          0.119             0.901
 6      0.142      0.294          0.152             1.072
 7      0.150      0.334          0.184             1.227
 8      0.157      0.371          0.214             1.368
 9      0.163      0.407          0.244             1.496
10      0.168      0.440          0.272             1.614
11      0.173      0.471          0.298             1.721
12      0.178      0.501          0.324             1.820
13      0.182      0.529          0.347             1.911
14      0.186      0.556          0.370             1.994
15      0.189      0.581          0.392             2.070
```

```
LETHAL RADIUS-RANGE=    40.0
LETHAL RADIUS-DEFLECTION=    40.0

MEAN TARGET LOCATION ERROR-RANGE= -158.1
MEAN TARGET LOCATION ERROR-DEFLECTION=    32.0

TARGET DENSITY STANDARD DEVIATION-RANGE=     8.3
TARGET DENSITY STANDARD DEVIATION-DEFLECTION=     8.3

BALLISTIC ERROR STANDARD DEVIATION-RANGE=    19.3
BALLISTIC ERROR STANDARD DEVIATION-DEFLECTION=     4.4

TARGET LOCATION ERROR STANDARD DEVIATION-RANGE=   778.3
TARGET LOCATION ERROR STANDARD DEVIATION-DEFLECTION=    94.9

N       AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1      0.019      0.019          0.0               0.0
 2      0.028      0.037          0.008             0.290
 3      0.035      0.055          0.020             0.560
 4      0.040      0.072          0.032             0.811
 5      0.044      0.089          0.046             1.048
 6      0.047      0.106          0.059             1.273
 7      0.049      0.123          0.073             1.486
 8      0.052      0.139          0.087             1.691
 9      0.054      0.155          0.101             1.886
10      0.055      0.171          0.115             2.075
11      0.057      0.186          0.129             2.256
12      0.059      0.201          0.142             2.430
13      0.060      0.216          0.156             2.599
14      0.061      0.230          0.169             2.762
15      0.062      0.245          0.182             2.920
```

```
LETHAL RADIUS-RANGE=   40.0
LETHAL RADIUS-DEFLECTION=   40.0

MEAN TARGET LOCATION ERROR-RANGE= -158.1
MEAN TARGET LOCATION ERROR-DEFLECTION=   32.0

TARGET DENSITY STANDARD DEVIATION-RANGE=    8.3
TARGET DENSITY STANDARD DEVIATION-DEFLECTION=    8.3

BALLISTIC ERROR STANDARD DEVIATION-RANGE=   19.3
BALLISTIC ERROR STANDARD DEVIATION-DEFLECTION=    4.4

TARGET LOCATION ERROR STANDARD DEVIATION-RANGE= 1366.9
TARGET LOCATION ERROR STANDARD DEVIATION-DEFLECTION=   94.9

N      AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1     0.011       0.011           0.0               0.0
 2     0.016       0.021           0.005             0.295
 3     0.020       0.032           0.012             0.572
 4     0.023       0.042           0.019             0.832
 5     0.025       0.052           0.027             1.080
 6     0.027       0.063           0.036             1.316
 7     0.029       0.073           0.044             1.544
 8     0.030       0.083           0.053             1.763
 9     0.031       0.092           0.061             1.975
10     0.032       0.102           0.070             2.181
11     0.033       0.112           0.079             2.381
12     0.034       0.121           0.087             2.576
13     0.035       0.131           0.096             2.765
14     0.035       0.140           0.105             2.950
15     0.036       0.149           0.113             3.131
```

```
LETHAL RADIUS-RANGE=   40.0
LETHAL RADIUS-DEFLECTION=   40.0

MEAN TARGET LOCATION ERROR-RANGE= -158.1
MEAN TARGET LOCATION ERROR-DEFLECTION=   32.0

TARGET DENSITY STANDARD DEVIATION-RANGE=    8.3
TARGET DENSITY STANDARD DEVIATION-DEFLECTION=    8.3

BALLISTIC ERROR STANDARD DEVIATION-RANGE=   38.5
BALLISTIC ERROR STANDARD DEVIATION-DEFLECTION=    7.4

TARGET LOCATION ERROR STANDARD DEVIATION-RANGE=  163.1
TARGET LOCATION ERROR STANDARD DEVIATION-DEFLECTION=   94.9

N      AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1     0.056       0.056           0.0               0.0
 2     0.092       0.109           0.018             0.191
 3     0.116       0.159           0.043             0.369
 4     0.135       0.206           0.072             0.531
 5     0.149       0.251           0.101             0.680
 6     0.161       0.293           0.131             0.815
 7     0.171       0.332           0.161             0.938
 8     0.180       0.370           0.189             1.051
 9     0.188       0.405           0.217             1.154
10     0.195       0.439           0.243             1.248
11     0.201       0.470           0.269             1.335
12     0.207       0.500           0.293             1.414
13     0.212       0.528           0.316             1.487
14     0.217       0.554           0.337             1.554
15     0.222       0.579           0.358             1.615
```

```
LETHAL RADIUS-RANGE=   40.0
LETHAL RADIUS-DEFLECTION=   40.0

MEAN TARGET LOCATION ERROR-RANGE= -158.1
MEAN TARGET LOCATION ERROR-DEFLECTION=   32.0

TARGET DENSITY STANDARD DEVIATION-RANGE=    8.3
TARGET DENSITY STANDARD DEVIATION-DEFLECTION=    8.3

BALLISTIC ERROR STANDARD DEVIATION-RANGE=   38.5
BALLISTIC ERROR STANDARD DEVIATION-DEFLECTION=    7.4

TARGET LOCATION ERROR STANDARD DEVIATION-RANGE=  778.3
TARGET LOCATION ERROR STANDARD DEVIATION-DEFLECTION=   94.9

N      AFTK     AFTK(INDEP)   DIFF(ABSOLUTE)   DIFF(RELATIVE)

 1     0.018     0.018          0.0              0.0
 2     0.030     0.037          0.006            0.214
 3     0.038     0.054          0.016            0.420
 4     0.044     0.072          0.027            0.618
 5     0.049     0.089          0.040            0.807
 6     0.053     0.106          0.053            0.988
 7     0.057     0.122          0.066            1.161
 8     0.060     0.139          0.079            1.326
 9     0.062     0.155          0.092            1.485
10     0.065     0.170          0.106            1.639
11     0.067     0.186          0.119            1.786
12     0.069     0.201          0.132            1.929
13     0.070     0.215          0.145            2.066
14     0.072     0.230          0.158            2.199
15     0.073     0.244          0.171            2.328
```

```
LETHAL RADIUS-RANGE=   40.0
LETHAL RADIUS-DEFLECTION=   40.0

MEAN TARGET LOCATION ERROR-RANGE= -158.1
MEAN TARGET LOCATION ERROR-DEFLECTION=   32.0

TARGET DENSITY STANDARD DEVIATION-RANGE=    8.3
TARGET DENSITY STANDARD DEVIATION-DEFLECTION=    8.3

BALLISTIC ERROR STANDARD DEVIATION-RANGE=   38.5
BALLISTIC ERROR STANDARD DEVIATION-DEFLECTION=    7.4

TARGET LOCATION ERROR STANDARD DEVIATION-RANGE= 1366.9
TARGET LOCATION ERROR STANDARD DEVIATION-DEFLECTION=   94.9

N      AFTK     AFTK(INDEP)   DIFF(ABSOLUTE)   DIFF(RELATIVE)

 1     0.011     0.011          0.0              0.0
 2     0.017     0.021          0.004            0.218
 3     0.022     0.032          0.010            0.431
 4     0.026     0.042          0.016            0.637
 5     0.029     0.052          0.024            0.835
 6     0.031     0.062          0.032            1.025
 7     0.033     0.072          0.040            1.210
 8     0.035     0.082          0.048            1.388
 9     0.036     0.092          0.056            1.561
10     0.037     0.102          0.065            1.729
11     0.039     0.112          0.073            1.892
12     0.040     0.121          0.081            2.051
13     0.041     0.130          0.090            2.206
14     0.042     0.140          0.098            2.358
15     0.042     0.149          0.106            2.505
```

```
LETHAL RADIUS-RANGE=   40.0
LETHAL RADIUS-DEFLECTION=   40.0

MEAN TARGET LOCATION ERROR-RANGE= -158.1
MEAN TARGET LOCATION ERROR-DEFLECTION=   32.0

TARGET DENSITY STANDARD DEVIATION-RANGE=    8.3
TARGET DENSITY STANDARD DEVIATION-DEFLECTION=    8.3

BALLISTIC ERROR STANDARD DEVIATION-RANGE=   56.3
BALLISTIC ERROR STANDARD DEVIATION-DEFLECTION=   14.8

TARGET LOCATION ERROR STANDARD DEVIATION-RANGE=  163.1
TARGET LOCATION ERROR STANDARD DEVIATION-DEFLECTION=   94.9

N       AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1      0.055      0.055            0.0              0.0
 2      0.095      0.108            0.013            0.133
 3      0.125      0.157            0.032            0.260
 4      0.148      0.204            0.056            0.379
 5      0.167      0.248            0.081            0.489
 6      0.182      0.290            0.108            0.591
 7      0.195      0.329            0.134            0.685
 8      0.207      0.366            0.160            0.772
 9      0.217      0.401            0.185            0.852
10      0.226      0.435            0.209            0.925
11      0.234      0.466            0.232            0.993
12      0.241      0.496            0.254            1.055
13      0.248      0.523            0.276            1.112
14      0.254      0.550            0.296            1.164
15      0.260      0.575            0.315            1.213
```

```
LETHAL RADIUS-RANGE=   40.0
LETHAL RADIUS-DEFLECTION=   40.0

MEAN TARGET LOCATION ERROR-RANGE= -158.1
MEAN TARGET LOCATION ERROR-DEFLECTION=   32.0

TARGET DENSITY STANDARD DEVIATION-RANGE=    8.3
TARGET DENSITY STANDARD DEVIATION-DEFLECTION=    8.3

BALLISTIC ERROR STANDARD DEVIATION-RANGE=   56.3
BALLISTIC ERROR STANDARD DEVIATION-DEFLECTION=   14.8

TARGET LOCATION ERROR STANDARD DEVIATION-RANGE=  778.3
TARGET LOCATION ERROR STANDARD DEVIATION-DEFLECTION=   94.9

N       AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1      0.018      0.018            0.0              0.0
 2      0.031      0.036            0.005            0.154
 3      0.041      0.054            0.013            0.306
 4      0.049      0.071            0.022            0.455
 5      0.055      0.088            0.033            0.599
 6      0.060      0.105            0.045            0.738
 7      0.065      0.122            0.057            0.873
 8      0.069      0.138            0.069            1.003
 9      0.072      0.153            0.081            1.128
10      0.075      0.169            0.094            1.250
11      0.078      0.184            0.106            1.367
12      0.080      0.199            0.119            1.480
13      0.083      0.214            0.131            1.589
14      0.085      0.228            0.144            1.696
15      0.087      0.242            0.156            1.798
```

```
LETHAL RADIUS-RANGE=   40.0
LETHAL RADIUS-DEFLECTION=   40.0

MEAN TARGET LOCATION ERROR-RANGE= -158.1
MEAN TARGET LOCATION ERROR-DEFLECTION=   32.0

TARGET DENSITY STANDARD DEVIATION-RANGE=    8.3
TARGET DENSITY STANDARD DEVIATION-DEFLECTION=    8.3

BALLISTIC ERROR STANDARD DEVIATION-RANGE=   56.3
BALLISTIC ERROR STANDARD DEVIATION-DEFLECTION=   14.8

TARGET LOCATION ERROR STANDARD DEVIATION-RANGE= 1366.9
TARGET LOCATION ERROR STANDARD DEVIATION-DEFLECTION=   94.9

N      AFTK    AFTK(INDEP)   DIFF(ABSOLUTE)   DIFF(RELATIVE)

 1     0.011      0.011          0.0              0.0
 2     0.018      0.021          0.003            0.158
 3     0.024      0.032          0.008            0.316
 4     0.028      0.042          0.013            0.471
 5     0.032      0.052          0.020            0.622
 6     0.035      0.062          0.027            0.770
 7     0.038      0.072          0.034            0.915
 8     0.040      0.082          0.042            1.055
 9     0.042      0.092          0.050            1.192
10     0.044      0.101          0.058            1.325
11     0.045      0.111          0.066            1.455
12     0.047      0.120          0.074            1.582
13     0.048      0.130          0.082            1.706
14     0.049      0.139          0.090            1.826
15     0.050      0.148          0.098            1.945
```

```
LETHAL RADIUS-RANGE=   47.5
LETHAL RADIUS-DEFLECTION=   47.5

MEAN TARGET LOCATION ERROR-RANGE= -158.1
MEAN TARGET LOCATION ERROR-DEFLECTION=   32.0

TARGET DENSITY STANDARD DEVIATION-RANGE=    8.3
TARGET DENSITY STANDARD DEVIATION-DEFLECTION=    8.3

BALLISTIC ERROR STANDARD DEVIATION-RANGE=   29.7
BALLISTIC ERROR STANDARD DEVIATION-DEFLECTION=    7.4

TARGET LOCATION ERROR STANDARD DEVIATION-RANGE=  163.1
TARGET LOCATION ERROR STANDARD DEVIATION-DEFLECTION=   94.9

N       AFTK     AFTK(INDEP)   DIFF(ABSOLUTE)   DIFF(RELATIVE)

 1      0.077      0.077          0.0              0.0
 2      0.120      0.148          0.028            0.234
 3      0.148      0.214          0.065            0.440
 4      0.169      0.274          0.105            0.621
 5      0.185      0.330          0.145            0.781
 6      0.199      0.382          0.183            0.921
 7      0.210      0.429          0.219            1.045
 8      0.220      0.473          0.254            1.155
 9      0.228      0.514          0.286            1.252
10      0.236      0.551          0.315            1.339
11      0.242      0.586          0.343            1.415
12      0.249      0.618          0.369            1.483
13      0.254      0.647          0.393            1.544
14      0.260      0.674          0.415            1.597
15      0.264      0.699          0.435            1.645
```

```
LETHAL RADIUS-RANGE=   47.5
LETHAL RADIUS-DEFLECTION=   47.5

MEAN TARGET LOCATION ERROR-RANGE= -158.1
MEAN TARGET LOCATION ERROR-DEFLECTION=   32.0

TARGET DENSITY STANDARD DEVIATION-RANGE=    8.3
TARGET DENSITY STANDARD DEVIATION-DEFLECTION=    8.3

BALLISTIC ERROR STANDARD DEVIATION-RANGE=   29.7
BALLISTIC ERROR STANDARD DEVIATION-DEFLECTION=    7.4

TARGET LOCATION ERROR STANDARD DEVIATION-RANGE=  778.3
TARGET LOCATION ERROR STANDARD DEVIATION-DEFLECTION=   94.9

N       AFTK     AFTK(INDEP)   DIFF(ABSOLUTE)   DIFF(RELATIVE)

 1      0.025      0.025          0.0              0.0
 2      0.040      0.050          0.011            0.266
 3      0.049      0.074          0.025            0.516
 4      0.056      0.098          0.042            0.750
 5      0.061      0.121          0.059            0.969
 6      0.066      0.143          0.077            1.176
 7      0.069      0.165          0.095            1.373
 8      0.073      0.186          0.113            1.559
 9      0.075      0.207          0.131            1.736
10      0.078      0.227          0.149            1.906
11      0.080      0.246          0.166            2.068
12      0.082      0.265          0.183            2.223
13      0.084      0.284          0.200            2.371
14      0.086      0.302          0.216            2.514
15      0.088      0.320          0.232            2.651
```

```
LETHAL RADIUS-RANGE=   47.5
LETHAL RADIUS-DEFLECTION=   47.5

MEAN TARGET LOCATION ERROR-RANGE= -158.1
MEAN TARGET LOCATION ERROR-DEFLECTION=   32.0

TARGET DENSITY STANDARD DEVIATION-RANGE=    8.3
TARGET DENSITY STANDARD DEVIATION-DEFLECTION=    8.3

BALLISTIC ERROR STANDARD DEVIATION-RANGE=   29.7
BALLISTIC ERROR STANDARD DEVIATION-DEFLECTION=    7.4

TARGET LOCATION ERROR STANDARD DEVIATION-RANGE= 1366.9
TARGET LOCATION ERROR STANDARD DEVIATION-DEFLECTION=   94.9

N      AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1     0.015       0.015           0.0              0.0
 2     0.023       0.029           0.006            0.273
 3     0.028       0.043           0.015            0.532
 4     0.032       0.057           0.025            0.777
 5     0.035       0.071           0.036            1.010
 6     0.038       0.085           0.047            1.233
 7     0.040       0.098           0.058            1.447
 8     0.042       0.112           0.070            1.653
 9     0.044       0.125           0.081            1.851
10     0.045       0.137           0.092            2.043
11     0.046       0.150           0.104            2.229
12     0.048       0.163           0.115            2.409
13     0.049       0.175           0.126            2.584
14     0.050       0.187           0.137            2.754
15     0.051       0.199           0.148            2.919
```

```
LETHAL RADIUS-RANGE=   47.5
LETHAL RADIUS-DEFLECTION=   47.5

MEAN TARGET LOCATION ERROR-RANGE= -158.1
MEAN TARGET LOCATION ERROR-DEFLECTION=   32.0

TARGET DENSITY STANDARD DEVIATION-RANGE=    8.3
TARGET DENSITY STANDARD DEVIATION-DEFLECTION=    8.3

BALLISTIC ERROR STANDARD DEVIATION-RANGE=   51.9
BALLISTIC ERROR STANDARD DEVIATION-DEFLECTION=   14.8

TARGET LOCATION ERROR STANDARD DEVIATION-RANGE=  163.1
TARGET LOCATION ERROR STANDARD DEVIATION-DEFLECTION=   94.9

N      AFTK     AFTK(INDEP)    DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1     0.076       0.076           0.0              0.0
 2     0.126       0.146           0.020            0.160
 3     0.162       0.211           0.050            0.307
 4     0.188       0.271           0.083            0.440
 5     0.209       0.327           0.117            0.560
 6     0.227       0.378           0.151            0.667
 7     0.241       0.425           0.184            0.762
 8     0.254       0.469           0.215            0.847
 9     0.265       0.509           0.244            0.923
10     0.275       0.547           0.272            0.990
11     0.283       0.581           0.298            1.050
12     0.291       0.613           0.322            1.103
13     0.299       0.642           0.344            1.151
14     0.305       0.670           0.364            1.193
15     0.312       0.695           0.383            1.230
```

```
LETHAL RADIUS-RANGE=   47.5
LETHAL RADIUS-DEFLECTION=   47.5

MEAN TARGET LOCATION ERROR-RANGE= -158.1
MEAN TARGET LOCATION ERROR-DEFLECTION=   32.0

TARGET DENSITY STANDARD DEVIATION-RANGE=    8.3
TARGET DENSITY STANDARD DEVIATION-DEFLECTION=    8.3

BALLISTIC ERROR STANDARD DEVIATION-RANGE=   51.9
BALLISTIC ERROR STANDARD DEVIATION-DEFLECTION=   14.8

TARGET LOCATION ERROR STANDARD DEVIATION-RANGE=  778.3
TARGET LOCATION ERROR STANDARD DEVIATION-DEFLECTION=   94.9

N      AFTK     AFTK(INDEP)   DIFF(ABSOLUTE)   DIFF(RELATIVE)

 1     0.025      0.025          0.0              0.0
 2     0.042      0.050          0.008            0.190
 3     0.054      0.074          0.020            0.374
 4     0.063      0.097          0.034            0.551
 5     0.070      0.120          0.050            0.720
 6     0.075      0.142          0.066            0.882
 7     0.080      0.163          0.083            1.036
 8     0.085      0.185          0.100            1.183
 9     0.088      0.205          0.117            1.324
10     0.092      0.225          0.134            1.458
11     0.095      0.245          0.150            1.587
12     0.097      0.264          0.166            1.711
13     0.100      0.282          0.182            1.829
14     0.102      0.300          0.198            1.943
15     0.104      0.318          0.214            2.052
```

```
LETHAL RADIUS-RANGE=   47.5
LETHAL RADIUS-DEFLECTION=   47.5

MEAN TARGET LOCATION ERROR-RANGE= -158.1
MEAN TARGET LOCATION ERROR-DEFLECTION=   32.0

TARGET DENSITY STANDARD DEVIATION-RANGE=    8.3
TARGET DENSITY STANDARD DEVIATION-DEFLECTION=    8.3

BALLISTIC ERROR STANDARD DEVIATION-RANGE=   51.9
BALLISTIC ERROR STANDARD DEVIATION-DEFLECTION=   14.8

TARGET LOCATION ERROR STANDARD DEVIATION-RANGE= 1366.9
TARGET LOCATION ERROR STANDARD DEVIATION-DEFLECTION=   94.9

N      AFTK     AFTK(INDEP)   DIFF(ABSOLUTE)   DIFF(RELATIVE)

 1     0.015      0.015          0.0              0.0
 2     0.024      0.029          0.005            0.196
 3     0.031      0.043          0.012            0.388
 4     0.036      0.057          0.021            0.575
 5     0.040      0.071          0.030            0.756
 6     0.044      0.084          0.041            0.930
 7     0.047      0.098          0.051            1.099
 8     0.049      0.111          0.062            1.262
 9     0.051      0.124          0.073            1.419
10     0.053      0.137          0.083            1.572
11     0.055      0.149          0.094            1.720
12     0.056      0.162          0.105            1.864
13     0.058      0.174          0.116            2.004
14     0.059      0.186          0.127            2.140
15     0.060      0.198          0.137            2.273
```

```
LETHAL RADIUS-RANGE=   47.5
LETHAL RADIUS-DEFLECTION=   47.5

MEAN TARGET LOCATION ERROR-RANGE= -158.1
MEAN TARGET LOCATION ERROR-DEFLECTION=   32.0

TARGET DENSITY STANDARD DEVIATION-RANGE=    8.3
TARGET DENSITY STANDARD DEVIATION-DEFLECTION=    8.3

BALLISTIC ERROR STANDARD DEVIATION-RANGE=   93.4
BALLISTIC ERROR STANDARD DEVIATION-DEFLECTION=   25.2

TARGET LOCATION ERROR STANDARD DEVIATION-RANGE=  163.1
TARGET LOCATION ERROR STANDARD DEVIATION-DEFLECTION=   94.9

N       AFTK      AFTK(INDEP)    DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1      0.073       0.073           0.0              0.0
 2      0.130       0.141           0.011            0.081
 3      0.176       0.204           0.028            0.157
 4      0.213       0.262           0.049            0.228
 5      0.244       0.316           0.072            0.294
 6      0.270       0.366           0.096            0.354
 7      0.292       0.412           0.120            0.409
 8      0.312       0.455           0.143            0.460
 9      0.329       0.495           0.166            0.505
10      0.344       0.532           0.188            0.547
11      0.357       0.566           0.209            0.584
12      0.370       0.598           0.228            0.617
13      0.381       0.627           0.246            0.647
14      0.391       0.654           0.263            0.674
15      0.400       0.680           0.279            0.698
```

```
LETHAL RADIUS-RANGE=   47.5
LETHAL RADIUS-DEFLECTION=   47.5

MEAN TARGET LOCATION ERROR-RANGE= -158.1
MEAN TARGET LOCATION ERROR-DEFLECTION=   32.0

TARGET DENSITY STANDARD DEVIATION-RANGE=    8.3
TARGET DENSITY STANDARD DEVIATION-DEFLECTION=    8.3

BALLISTIC ERROR STANDARD DEVIATION-RANGE=   93.4
BALLISTIC ERROR STANDARD DEVIATION-DEFLECTION=   25.2

TARGET LOCATION ERROR STANDARD DEVIATION-RANGE=  778.3
TARGET LOCATION ERROR STANDARD DEVIATION-DEFLECTION=   94.9

N       AFTK      AFTK(INDEP)    DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1      0.025       0.025           0.0              0.0
 2      0.044       0.049           0.005            0.106
 3      0.060       0.072           0.013            0.210
 4      0.072       0.095           0.023            0.313
 5      0.083       0.117           0.034            0.413
 6      0.092       0.139           0.047            0.511
 7      0.100       0.160           0.061            0.606
 8      0.107       0.181           0.074            0.698
 9      0.113       0.201           0.089            0.787
10      0.118       0.221           0.103            0.873
11      0.123       0.240           0.117            0.956
12      0.127       0.259           0.132            1.036
13      0.131       0.277           0.146            1.114
14      0.135       0.295           0.160            1.188
15      0.138       0.312           0.174            1.260
```

```
LETHAL RADIUS-RANGE=   47.5
LETHAL RADIUS-DEFLECTION=   47.5

MEAN TARGET LOCATION ERROR-RANGE= -158.1
MEAN TARGET LOCATION ERROR-DEFLECTION=   32.0

TARGET DENSITY STANDARD DEVIATION-RANGE=    8.3
TARGET DENSITY STANDARD DEVIATION-DEFLECTION=    8.3

BALLISTIC ERROR STANDARD DEVIATION-RANGE=   93.4
BALLISTIC ERROR STANDARD DEVIATION-DEFLECTION=   25.2

TARGET LOCATION ERROR STANDARD DEVIATION-RANGE= 1366.9
TARGET LOCATION ERROR STANDARD DEVIATION-DEFLECTION=   94.9

N     AFTK     AFTK(INDEP)   DIFF(ABSOLUTE)    DIFF(RELATIVE)

 1    0.014      0.014         0.0              0.0
 2    0.026      0.028         0.003            0.111
 3    0.035      0.042         0.008            0.222
 4    0.042      0.056         0.014            0.332
 5    0.048      0.070         0.021            0.441
 6    0.054      0.083         0.029            0.548
 7    0.058      0.096         0.038            0.654
 8    0.062      0.109         0.047            0.757
 9    0.066      0.122         0.056            0.858
10    0.069      0.134         0.066            0.956
11    0.071      0.147         0.075            1.053
12    0.074      0.159         0.085            1.147
13    0.076      0.171         0.095            1.238
14    0.079      0.183         0.104            1.328
15    0.081      0.195         0.114            1.415
```

APPENDIX C

COMPUTER PROGRAM FOR ONE DIMENSION MODEL

```
C           THIS PROGRAM COMPUTES INDEPENDENT AND DEPENDENT
C           KILL PROBABILITIES FOR THE ONE DIMENSIONAL SALVO
C           MODEL WITH THE FOLLOWING INPUT VARIABLES:
C                 LETHAL RADIUS(A)
C                 MEAN AIM POINT(AMU)
C                 TARGET LOCATION ERROR STD. DEV.(SIGA)
C                 BALLISTIC ERROR STD. DEV.(SIGD)
C
C
C           THE PROGRAM USES DOUBLE PRECISION.
        IMPLICIT REAL*8(A-H,O-Z)
C
C
C           THE FOLLOWING MUST BE DIMENSIONED TO NRDS, THE
C           MAXIMUM NUMBER OF ROUNDS FIRED IN THE SALVO.
        DIMENSION TERM(15),PKILL(15),PINDEP(15),DIFF(15),
       1DIFREL(15)
        NRDS=15
C
C
C           CANCEL IS CALLED TO SUPRESS UNDERFLOW MESSAGES.
        CALL CANCEL(2)
C
C
C           MM AND NN ARE COUNTERS USED TO CONTROL FORMAT.
        MM=3
        NN=1
C
C
C           THE FOLLOWING START AND STOP VALUES OF LOOP
C           PARAMETERS ARE ACTUAL VALUE PLUS ONE.
        DO 102 IA=11,51,20
        DO 102 IAMU=1,201,100
        DO 102 ISIGA=1,401,200
        DO 102 ISIGD= 1,61,30
C
C
        MM=MM+1
        INDIC=MM-3*NN
C
C
C           CONVERT INTEGER VALUES TO FLOATING POINT DOUBLE
C           PRECISION.
        A=DFLOAT(IA-1)
        AMU=DFLOAT(IAMU-1)
        SIGD=DFLOAT(ISIGD-1)
        SIGA=DFLOAT(ISIGA-1)
C
C
        VARD=SIGD**2
        VARA=SIGA**2
        IF(INDIC.EQ.1) GO TO 97
   99   WRITE(06,1000) A,AMU,VARA,VARD
 1000   FORMAT('0',//,022X,'LETHAL RADIUS=',F7.1,/,
       122X,'MEAN AIM POINT=',F7.1,/,
       222X,'TARGET LOCATION ERROR VARIANCE=',F10.1,/,
       322X,'BALLISTIC ERROR VARIANCE=',F10.1,//,22X,'N',05X,
       4'PKILL',3X,'PKILL(INDEP)',3X,'DIFF(ABSOLUTE)',3X,
       5'DIFF(RELATIVE)',/)
        GO TO 96
   97   WRITE(06,1002) A,AMU,VARA,VARD
 1002   FORMAT('1',////,22X,'LETHAL RADIUS=',F7.1,/,
       122X,'MEAN AIM POINT=',F7.1,/,
       222X,'TARGET LOCATION ERROR VARIANCE=',F10.1,/,
       322X,'BALLISTIC ERROR VARIANCE=',F10.1,//,22X,'N',05X,
       4'PKILL',3X,'PKILL(INDEP)',3X,'DIFF(ABSOLUTE)',3X,
```

```
     5'DIFF(RELATIVE)',/)
      NN=NN+1
   96 DO 102 N=1,NRDS
      DO 100 K=1,N
      AN=DFLOAT(N)
      AK=DFLOAT(K)
      BINOMC=DGAMMA(AN+1.0)/(DGAMMA(AK+1.0)*
     1DGAMMA(AN-AK+1.0))
      TERM2A=A**2+VARD
      TERM2=((-1.0)**(K-1))*(A/DSQRT(TERM2A))**(K-1)
      TERM3A=TERM2A+AK*VARA
      TERM3B=-.5*((AK*AMU**2)/TERM3A)
      TERM3=DEXP(TERM3B)/DSQRT(TERM3A)
      TERM(K)=BINOMC*TERM2*TERM3
  100 CONTINUE
      SUM=0.0
      DO 101 K=1,N
      SUM=SUM+TERM(K)
  101 CONTINUE
      PKILL(N)=A*SUM
      PINDEP(N)=1.0-(1.0-PKILL(1))**N
      DIFF(N)=PINDEP(N)-PKILL(N)
      IF(DIFF(N).LT.0.0005) GO TO 103
      DIFREL(N)=DIFF(N)/PKILL(N)
      GO TO 104
  103 DIFF(N)=0.0
      DIFREL(N)=0.0
  104 WRITE(06,1001) N,PKILL(N),PINDEP(N),DIFF(N),DIFREL(N)
 1001 FORMAT(21X,I3,F9.3,F11.3,F16.3,F17.3)
  102 CONTINUE
   98 STOP
      END
```

APPENDIX D

COMPUTER PROGRAM FOR TWO DIMENSION MODEL WITH CIRCULAR NORMAL DISTRIBUTIONS

```
C
C          THIS PROGRAM COMPUTES INDEPENDENT AND DEPENDENT
C          AVERAGE FRACTIONS OF TARGETS KILLED FOR THE TWO
C          DIMENSIONAL SALVO MODEL WITH CIRCULAR NORMAL
C          LETHALITY, TARGET DENSITY, TARGET LOCATION ERROR
C          AND BALLISTIC ERROR DISTRIBUTIONS, AND THE
C          FOLLOWING INPUT VARIABLES:
C                LETHAL RADIUS(A)
C                TARGET LOCATION ERROR STD. DEV.(SIGA)
C                BALLISTIC ERROR STD. DEV.(SIGD)
C                TARGET DENSITY STD. DEV.(SIGT)
C
C
C          THE PROGRAM USES DOUBLE PRECISION.
      IMPLICIT REAL*8(A-H,O-Z)
C
C
C          THE FOLLOWING MUST BE DIMENSIONED TO NRDS, THE
C          MAXIMUM NUMBER OF ROUNDS FIRED IN THE SALVO.
      DIMENSION TERM(15),F(15),TERMIN(15),DIFF(15),
     1DIFREL(15)
      NRDS=15
C
C
C          MM AND NN ARE COUNTERS USED TO CONTROL FORMAT.
      MM=3
      NN=1
C
C
C          THE FOLLOWING START AND STOP VALUES OF LOOP
C          PARAMETERS ARE ACTUAL VALUE PLUS ONE.
      DO 100 IA=11,51,20
      DO 100 ISIGT= 11,211,100
      DO 100 ISIGA=1,401,200
      DO 100 ISIGD= 1,61,30
C
C
      MM=MM+1
      INDIC=MM-3*NN
C
C
C          CONVERT INTEGER VALUES TO FLOATING POINT DOUBLE
C          PRECISION.
      A=DFLOAT(IA-1)
      SIGA=DFLOAT(ISIGA-1)
      SIGD=DFLOAT(ISIGD-1)
      SIGT=DFLOAT(ISIGT-1)
C
C
      AVAR=SIGA**2
      DVAR=SIGD**2
      TVAR=SIGT**2
      ASQ=A**2
      P=ASQ/(ASQ+DVAR)
      Q=(ASQ+DVAR)/(AVAR+TVAR)
      IF(INDIC.EQ.1) GO TO 97
   99 WRITE(06,1000) A,TVAR,AVAR,DVAR
 1000 FORMAT('0',//,022X,'LETHAL RADIUS=',F7.1,/,
     122X,'TARGET DENSITY VARIANCE=',F10.1,/,
     222X,'TARGET LOCATION ERROR VARIANCE=',F10.1,/,
     322X,'BALLISTIC ERROR VARIANCE=',F10.1,//,22X,'N',06X,
     4'AFTK',4X,'AFTK(INDEP)',3X,'DIFF(ABSOLUTE)',3X,
     5'DIFF(RELATIVE)',/)
      GO TO 96
   97 WRITE(06,1002) A, TVAR,AVAR,DVAR
 1002 FORMAT('1',////,22X,'LETHAL RADIUS=',F7.1,/,
```

```
     122X,'TARGET DENSITY VARIANCE=',F10.1,/,
     222X,'TARGET LOCATION ERROR VARIANCE=',F10.1,/,
     322X,'BALLISTIC ERROR VARIANCE=',F10.1,//,22X,'N',06X,
     4'AFTK',4X,'AFTK(INDEP)',3X,'DIFF(ABSOLUTE)',3X,
     5'DIFF(RELATIVE)',/)
      NN=NN+1
   96 DO 100 N=1,NRDS
      DO 101 K=1,N
      AN=DFLOAT(N)
      AK=DFLOAT(K)
      BINOMC=DGAMMA(AN+1.0)/(DGAMMA(AK+1.0)*
     1DGAMMA(AN-AK+1.0))
      TERM2=(-1.0)**(K-1)
      TERM3=P**K/(Q+AK)
      TERM(K)=BINOMC*TERM2*TERM3
  101 CONTINUE
      SUM=0.0
      DO 102 K=1,N
      SUM=SUM+TERM(K)
  102 CONTINUE
      F(N)=Q*SUM
      TERMIN(N)=1.0-(1.0-F(1))**N
      DIFF(N)=TERMIN(N)-F(N)
      IF(DIFF(N).LT.0.0005) GO TO 103
      DIFREL(N)=DIFF(N)/F(N)
      GO TO 104
  103 DIFF(N)=0.0
      DIFREL(N)=0.0
  104 WRITE(06,1001) N,F(N),TERMIN(N),DIFF(N),DIFREL(N)
 1001 FORMAT(21X,I3,F10.3,F11.3,F15.3,F17.3)
  100 CONTINUE
      STOP
```

APPENDIX E

COMPUTER PROGRAM FOR TWO DIMENSION MODEL WITH ELLIPTICAL NORMAL DISTRIBUTIONS

```
C          THIS PROGRAM COMPUTES INDEPENDENT AND DEPENDENT
C          AVERAGE FRACTIONS OF TARGET KILLED(AFTK) FOR THE
C          TWO DIMENSIONAL SALVO MODEL WITH ELLIPTICAL NORMAL
C          LETHALITY, TARGET DENSITY, TARGET LOCATION ERROR
C          AND BALLISTIC ERROR DISTRIBUTIONS.  INPUT DATA IN
C          THIS PROGRAM IS FOR THE 105MM HOWITZER CASE.
C          THE X COORDINATE IS RANGE AND THE Y COORDINATE IS
C          DEFLECTION.
C
C
C          THIS PROGRAM USES DOUBLE PRECISION.
      IMPLICIT REAL*8(A-H,O-Z)
C
C
C          THE FOLLOWING MUST BE DIMENSIONED TO NRDS, THE
C          MAXIMUM NUMBER OF ROUNDS FIRED IN THE SALVO.
      DIMENSION F(15),TERMIN(15),DIFF(15),TERM(15),
     1DIFREL(15)
      NRDS=15
C
C
C          INDIC IS A COUNTER TO CONTROL FORMAT.
      INDIC=1
C
C

      AX=15.0
      AY=15.0
      BX=-158.139
      BY=32.001
      SIGTX=8.30
      SIGTY=8.30
      SIGDX=11.86
      SIGDY=1.48
      SIGAY=94.89
   10 SIGAX=163.08
      CALL ELIP2D(AX,AY,BX,BY,SIGTX,SIGTY,SIGDX,SIGDY,
     1SIGAX,SIGAY,NRDS,F,TERMIN,DIFF,DIFREL)
      CALL WRITE (AX,AY,BX,BY,SIGTX,SIGTY,SIGDX,SIGDY,
     1SIGAX,SIGAY,NRDS,F,TERMIN,DIFF,INDIC,DIFREL)
      SIGAX=778.35
      CALL ELIP2D(AX,AY,BX,BY,SIGTX,SIGTY,SIGDX,SIGDY,
     1SIGAX,SIGAY,NRDS,F,TERMIN,DIFF,DIFREL)
      CALL WRITE (AX,AY,BX,BY,SIGTX,SIGTY,SIGDX,SIGDY,
     1SIGAX,SIGAY,NRDS,F,TERMIN,DIFF,INDIC,DIFREL)
      SIGAX=1366.94
      CALL ELIP2D(AX,AY,BX,BY,SIGTX,SIGTY,SIGDX,SIGDY,
     1SIGAX,SIGAY,NRDS,F,TERMIN,DIFF,DIFREL)
      CALL WRITE (AX,AY,BX,BY,SIGTX,SIGTY,SIGDX,SIGDY,
     1SIGAX,SIGAY,NRDS,F,TERMIN,DIFF,INDIC,DIFREL)
      IF(SIGDX.LT.15.0) GO TO 20
      IF(SIGDX.GT.25.0) GO TO 30
      SIGDX=28.17
      SIGDY=10.38
      GO TO 10
   20 SIGDX=16.31
      SIGDY=4.45
      GO TO 10
   30 STOP
      END
```

```
      SUBROUTINE ELIP2D(AX,AY,BX,BY,SIGTX,SIGTY,SIGDX,SIGDY,
     1SIGAX,SIGAY,NRDS,F,TERMIN,DIFF,DIFREL)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION F(NRDS),TERMIN(NRDS),DIFF(NRDS),TERM(15),
     1DIFREL(NRDS)
      AXSQ=AX**2
      AYSQ=AY**2
      BXSQ=BX**2
      BYSQ=BY**2
      AVARX=SIGAX**2
      AVARY=SIGAY**2
      DVARX=SIGDX**2
      DVARY=SIGDY**2
      TVARX=SIGTX**2
      TVARY=SIGTY**2
      PX=AXSQ/(AXSQ+DVARX)
      PY=AYSQ/(AYSQ+DVARY)
      QX=(AXSQ+DVARX)/(AVARX+TVARX)
      QY=(AYSQ+DVARY)/(AVARY+TVARY)
      DO 102 N=1,NRDS
      DO 100 K=1,N
      AN=DFLOAT(N)
      AK=DFLOAT(K)
      DXSQ=AXSQ+DVARX+AK*(AVARX+TVARX)
      DYSQ=AYSQ+DVARY+AK*(AVARY+TVARY)
      BINOMC=DGAMMA(AN+1.0)/(DGAMMA(AK+1.0)*
     1DGAMMA(AN-AK+1.0))
      TERM2=(-1.0)**(K-1)
      TERM3=(DSQRT(PX*PY))**K/DSQRT((QX+AK)*(QY+AK))
      TERM4=DEXP((-AK/2.0)*(BXSQ/DXSQ+BYSQ/DYSQ))
      TERM(K)=BINOMC*TERM2*TERM3*TERM4
  100 CONTINUE
      SUM=0.0
      DO 101 K=1,N
      SUM=SUM+TERM(K)
  101 CONTINUE
      F(N)=(DSQRT(QX*QY))*SUM
      TERMIN(N)=1.0-(1.0-F(1))**N
      DIFF(N)=TERMIN(N)-F(N)
      IF(DIFF(N).LT.0.0005) GO TO 103
      DIFREL(N)=DIFF(N)/F(N)
      GO TO 102
  103 DIFF(N)=0.0
      DIFREL(N)=0.0
  102 CONTINUE
      RETURN
      END


      SUBROUTINE WRITE (AX,AY,BX,BY,SIGTX,SIGTY,SIGDX,SIGDY,
     1SIGAX,SIGAY,NRDS,F,TERMIN,DIFF,INDIC,DIFREL)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION F(NRDS),TERMIN(NRDS),DIFF(NRDS),DIFREL(NRDS)
      IF(INDIC.EQ.0) GO TO 10
      WRITE (06,1000) AX,AY,BX,BY,SIGTX,SIGTY,SIGDX,SIGDY,
     1SIGAX,SIGAY
 1000 FORMAT('1',//,  22X,'LETHAL RADIUS-RANGE=',F7.1,/,
     122X,'LETHAL RADIUS-DEFLECTION=',F7.1,//,
     222X,'MEAN TARGET LOCATION ERROR-RANGE=',F7.1,/,
     322X,'MEAN TARGET LOCATION ERROR-DEFLECTION=',F7.1,//,
     422X,'TARGET DENSITY STANDARD DEVIATION-RANGE=',F7.1,/,
     522X,'TARGET DENSITY STANDARD DEVIATION-DEFLECTION=',
     6F7.1,//,22X,
     7'BALLISTIC ERROR STANDARD DEVIATION-RANGE=',F7.1,/,22X
     8,'BALLISTIC ERROR STANDARD DEVIATION-DEFLECTION=',
     9F7.1,//,22X,
     1'TARGET LOCATION ERROR STANDARD DEVIATION-RANGE=',
     2F7.1,/,22X,
```

```
     3'TARGET LOCATION ERROR STANDARD DEVIATION-DEFLECTION='
     4,F7.1,//,22X,'N',06X,'AFTK',4X,'AFTK(INDEP)',
     53X,'DIFF(ABSOLUTE)',3X,'DIFF(RELATIVE)',/)
      INDIC=0
      GO TO 20
   10 WRITE (06,1002) AX,AY,BX,BY,SIGTX,SIGTY,SIGDX,SIGDY,
     1SIGAX,SIGAY
 1002 FORMAT('0',////,22X,'LETHAL RADIUS-RANGE=',F7.1,/,
     122X,'LETHAL RADIUS-DEFLECTION=',F7.1,//,
     222X,'MEAN TARGET LOCATION ERROR-RANGE=',F7.1,/,
     322X,'MEAN TARGET LOCATION ERROR-DEFLECTION=',F7.1,//,
     422X,'TARGET DENSITY STANDARD DEVIATION-RANGE=',F7.1,/,
     522X,'TARGET DENSITY STANDARD DEVIATION-DEFLECTION=',
     6F7.1,//,22X,
     7'BALLISTIC ERROR STANDARD DEVIATION-RANGE=',F7.1,/,22X
     8,'BALLISTIC ERROR STANDARD DEVIATION-DEFLECTION=',
     9F7.1,//,22X,
     1'TARGET LOCATION ERROR STANDARD DEVIATION-RANGE=',
     2F7.1,/,22X,
     3'TARGET LOCATION ERROR STANDARD DEVIATION-DEFLECTION='
     4,F7.1,//,22X,'N',06X,'AFTK',4X,'AFTK(INDEP)',
     53X,'DIFF(ABSOLUTE)',3X,'DIFF(RELATIVE)',/)
      INDIC=1
   20 DO 100 N=1,NRDS
      WRITE(06,1001) N,F(N),TERMIN(N),DIFF(N),DIFREL(N)
 1001 FORMAT(21X,I3,F10.3,F11.3,F15.3,F17.3)
  100 CONTINUE
      RETURN
      END
```

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13. ABSTRACT

This thesis examines several models for the computation of target coverage when multiple rounds are fired at a target. Fractional kill of a fragment sensitive target by a fragmenting projectile as a function of the number of rounds fired is compared for two models. The first is a standard salvo-fire model in which N rounds are fired at the same aim point. In the second model, single shot kill probability is computed for a fragment sensitive target and then fractional kill from the firing of N rounds is computed according to the assumption that the effects of each round are independent. The need for sophisticated target coverage models (such as salvo-fire models) is demonstrated by the results of computations performed in this study.

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